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ABSTRACT

This issue of the journal of the Colorado Council of Teachers of Mathematics focuses on the role of technology--in particular, computers--in teaching mathematics, with overall philosophical issues of technology in education considered as well. Fourteen articles deal with the topics of: (1) Computers in American Schools: Philosophical and Political Issues; (2) Computers in the Schools--Boon or Boondoggle? (3) The Place of Computers in Teaching; (4) The Place of Technology in the Teaching of School Mathematics; (5) Opportunity is Knocking--Will We Respond? (6) School Mathematics and the Promise of Computing; (7) The Impact of Technology on the School Mathematics Curriculum; (8) A Systems View of Technology in the Teaching of School Mathematics; (9) Computer Science vs. Mathematics; (10) Using the Computer to Deliver Instruction in Mathematics; (11) Two Teachers for Sister Sarah; (12) Technology in the Teaching of Elementary School Mathematics; (13) Cherry Creek Equals in Computers: A Model for Staff Development; and (14) One Case Where the Computer Provides an Unquestioned Advantage. A report of a conference on the impact of computing technology is also reprinted. (MNS)

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Colorado Council of Teachers of Mathematics

May 1985 Volume 17 No. 4

THE PLACE OF TECHNOLOGY IN THE TEACHING OF SCHOOL MATHEMATICS

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A NOTE FROM THE EDITOR

This issue of the COLORADO MATHEMATICS TEACHER is devoted entirely to the topic of technology as it relates to the teaching of mathematics. The idea for this came from a meeting of the CCTM Board of Directors in the Fall of 1984. Efforts to put the issue together began in January 1985, with the result here before you. Early in the process of gathering articles, it was clear that the topic of technology does not fit neatly into content area boundaries as traditionally conceived. Because of this, some papers contained in this issue deal with the overall philosophical issue of technology in education as well as with how it relates to teaching mathematics. One of the bases for writing for authors of articles was the document from the National Council of Teachers of Mathematics (NCTM) titled THE IMPACT OF TECHNOLOGY ON SCHOOL MATHEMATICS: REPORT OF A CONFERENCE. Because of this, that entire document is reproduced within the following pages (see page 41).

This is the last of the issues of the CMT for which I will serve as editor. I notified the CCTM Board in January that I would be leaving the position as CCTM editor as of June 1, 1985. I want to thank the Board for their support, the authors of articles for their efforts, and all the friends that I have made because of being editor. I also want to encourage you to support the person(s) who will assume the duties of editor. It is a time consuming, and many times lonely, job.

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* *

Articles contained in this publication do not necessarily reflect the position of individual CCTM Board members, the editor, the CCTM Board, or membership of the CCTM.

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OF THE COLORADO COUNCIL OF TEACHERS OF MATHEMATICS

The COLORADO MATHEMATICS TEACHER
A publication of the Colorado Council of Teachers of Mathematics

Volume 17, Number 4 May, 1985

Single topic issue: THE ROLE OF TECHNOLOGY IN THE TEACHING OF SCHOOL MATHEMATICS

Marc Swadener, Editor

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The COLORADO MATHEMATICS TEACHER is a publication for members of the Colorado Council of Teachers of Mathematics. It is published four times yearly (September, November, February, and May). For information on membership contact Ms. Margilee Sauer, CCTM Sec/Treas., 510 Inca Parkway, Boulder, Colorado 80303.

COMPUTERS IN AMERICAN SCHOOLS: PHILOSOPHICAL AND POLITICAL ISSUES

Marie E. Wirsing
University of Colorado-Denver
Denver, Colorado

There is a clever television advertisement of the day that explains educational success and failure in terms of computer skills.

Scene one (the railroad depot): Mom and Dad fondly wave good-bye to their smiling college-bound son, and the train pulls away.

Scene two (the same railroad depot several months later): Mom and Dad tearfully meet their returning son, a dejected college drop-out. The message to the viewing audience: without computer training, a student simply is not equipped to make his way in the modern technological world. This powerful television mini-drama takes less than sixty seconds. Yet it effectively captures the prevailing educational mood and caters to the very real fears of many parents.

Parental pressure typically is cited as the primary reason why American schools--from the kindergarten to the university--have rushed to give computers a prominent place in the curriculum. The phenomenon recently was described by two educational computer consultants:

> "Most schools got computers out of sheer, unadulterated fear and had no idea what to do with them . . . They (the school boards) are getting a lot of pressure from parents because the parents are afraid that if the kids aren't computer literate, they won't be able to find employment."[1]

These parental fears have been heightened by the influential report of the National Commission on Excellence in Education. Released in April 1983, A NATION AT RISK warned that "a rising tide of mediocrity" had devastated public education. Elevating computer literacy to the status of a "new basic," the National Commission recommended that one-half year of computer science be required for all high school graduates.[2] Despite the superficial research employed in drafting A NATION AT RISK, the document subsequently encouraged a spate of similar educational reform proposals around the country. Almost without exception, state and local educational reform documents in the past few years have promoted computer instruction as a curriculum basic.[3]

The computer industry itself, it must be said, has fully exploited the new educational market of its own making. Two years ago, TIME magazine perceptively noted that Steven Jobs' donation of 10,000 Apple computers to California schools would get his company "good will, a generous tax break, and an even stronger foothold in . . . the youth market."[4]

It is not surprising that parental pressure, the unchallenged recommendations of educational task force groups, and computer industry hype have combined to bring about rapid and staggering results. In 1981, about 33,000 computers were lodged in American schools. By mid-1984 the number had soared to 630,000. By mid-1985 it is estimated that 1.5 million computers will be in the nation's classrooms.[5] Proponents of computerized instruction invariably express the belief that the presence and influence of the hardware in education will continue to grow--ultimately bringing about a dramatic change in learning modes and location.[6]

The computerizing of the nation's classrooms has not been without critics. But the bulk of criticism to date has focused on the poor quality of computer software.[7] And the present inferior condition of the software, we are advised, constitutes a problem that will lend itself to intelligent solution.[8] Significantly, among such critics there is no questioning of the role

and capability of the computer as an instructional device.

There is, however, at least one computer scientist who has identified the much more compelling problem surrounding computerized learning--a problem that has submerged in the selling of contemporary educational reform. Joseph Weizenbaum, MIT computer scientist, and inventor of ELIZA, has pointed out

> ". . . that giving children computers to play with . . . cannot touch . . . any real problem . . ."
>
> "The assertion that all human knowledge is encodable in streams of zeros and ones--philosophically, that's very hard to swallow. In effect, the whole world is made to seem computable. This generates a kind of tunnel vision, where the only problems that seem legitimate are problems that can be put on a computer. There is a whole world of real problems, of human problems, which is essentially ignored."[9]

In a conversation with this writer in November 1983, Weizenbaum commented that computer instruction in the schools masquerades as computer "science"--that teachers and students alike are exposed only to low-level programming activity. Weizenbaum insisted that a reasonably intelligent 18-year-old could learn all that was necessary to know about computer operation in a matter of a few weeks, and that schools therefore could more responsibility devote attention to other kinds of studies.

Weizenbaum's remarks illuminated a fundamental philosophic problem. All computer models are built in a way that incorporates one distinctive system of logic--the binary pattern of Boolean algebra. When a computer executes a program, a very wordy worksheet is transformed into a highly compact code; that code is then further reduced to a rigidly formatted bit string. The assumption is made within computer technology that this process of radical simplification does not result in the loss or distortion of essential information, and that the final product of the transformations (the string of zeros and ones) is identical in meaning to the language of the original worksheet.[10]

It is important to recognize that the Boolean pattern of thought is a derivative of Aristotelian philosophy and Newtonian science. Thus the popularly claimed "revolutionary" qualities of computer instruction are rooted in historic naivete. The underlying premises of the modern hardware date from the era of Classical Greece and the European Enlightenment. Moreover, it is crucial to understand that Aristotelian philosophy and Newtonian science form an intellectual tradition which always has assumed, at an unquestioned a priori level of thinking and valuing: the objectivity of knowledge; the universal agreement about the conclusions of knowledge propositions (the expectation of convergency learning outcomes); the legitimacy and intelligibility of subdividing knowledge into discrete, isolated "parts" and then advancing the learner part by part toward larger generalizations which are known in advance by the instructional agent; the universality of languaging (the primitive language commands built into each computer anticipate the intellectual tracking of teachers and students); and the operation of the Law of the Excluded Middle, or two-part logic (either/or thinking).

Stated succinctly, computerized instruction represents an intellectually truncated version of the Aristotelian-Newtonian tradition. All computers operate on the basis of two basic functions--"on" and "off"--and all knowledge sequences, however complex, must be designed to fit the on-off construction of the machine. The computer, by its procedural limitations of inputs and outputs, cannot accommodate nuances and non-linear thinking processes. The critical point is that the computer lodges control over knowledge interpretation in the program designer. Even if local districts and individuals were to reach a point where they designed their own software, the same intellectual and instructional limitations will persist. When used to interpret and

transmit knowledge, the computer forces the individual teacher and student to track with the idiosyncratic thought patterns of the programmer. Even Logo--a microworld approach which does not predetermine specific learning outcomes--still forces the user to define and name procedures within the Aristotelian-Newtonian boundaries of logic.

The ramifications of using computers, as a matter of public policy, as efficient instruments for knowledge interpretation and transmission in the nation's schools are, therefore, enormous. The inherent epistemological frame of reference is that of a delivery system, and it is a highly reductionist system in the quality of the knowledge it purports to deliver. Furthermore, educational policy that presumes that all teachers should teach in ways which accept the binary Boolean system completely ignores the existence of a whole range of other educational philosophies--intellectual orientations wherein binary thought patterns are alien to ideas about the nature of reality, knowledge, values, educational purposes, instructional practices, and notions of excellence.

The crux of the issue is a political one--the same one addressed by Alexis De Tocqueville 150 years ago: the omnipotence of the majority. Public schooling policy which channels instructional content and technique in a predetermined direction--by sheer weight of the omnipresence of the computers and accompanying administrative directives vis-a-vis anticipated usage by the teacher--constitutes a monolithic use of power. The widespread conviction that computers are an inevitable and laudable feature of the American landscape, might-makes-right arguments, and national hype do not legitimate this monolithic use of power in connection with the public schools of a democratic society, in Colorado or elsewhere.

I submit that only the individual classroom teacher is in a position to determine whether the epistemological rules under which computers function are compatible with his or her educational philosophy and related pedagogy. Only the individual classroom teacher is in a position to determine whether an isolated focus on objectified terminal behaviors constitutes a sensible and warranted instructional pursuit. And only the individual classroom teacher is in a position to assess the advantages of computer-assisted instruction against other pedagogical approaches. To remove these important decisions from the individual teacher is, in effect, to undermine professional judgment and replace it with a trained technician mode of operation.

There are, to be sure, computer advocates who openly scorn the ability of classroom teachers to function on the basis of informed professional judgment. Alfred Bork, in a recent call to restructure "training programs" for teachers, commented that

> "We like to believe that K-12 and college teachers develop their own courses, and this does happen occasionally--but only occasionally."

With the acceptance of this diminished view of teaching, the institution of predetermined curriculum content, including computer learning modules appears justified. In the final analysis, Bork's argument is a dangerous one. It not only reflects the arrogance of external curriculum control, it raises the ancient political specter: Who will guard the guardians?

NOTES

1. Nick Lombardi and Irene Danizger, as quoted by Stephen Miller, "Schools Squander Cash on Computers With Little Direction," ROCKY MOUNTAIN NEWS (March 5, 1985): 15-C.

2. National Commission on Excellence in Education, "An Open Letter to the American People, A Nation at Risk: The Imperative for Educational Reform," EDUCATION WEEK (April 27, 1983): 14.

3. See, for example, Colorado Department of Education, OPERATION RENAISSANCE (December 1983), pp. 40-42; John B. Peper, FREEDOM TO EXCEL FOR THE NEW CENTURY GENERATION, FOCUS ON EXCELLENCE IN LEARNING AND INSTRUCTION (Jefferson County Public Schools, Colorado: Spring 1984), p. 9; and Littleton Public Schools, FUTURES COMMITTEE REPORT (Littleton, Colorado: May 1984), pp. 16, 62-65, 96, 99.

4. Jay Cocks, "The Updated Book of Jobs," TIME (January 3, 1983): 27.

5. Stephen Miller, op. cit.

6. See, for example, Alfred Bork "Computers in Education Today--And Some Possible Futures," PHI DELTA KAPPAN (December 1984): 239-243.

7. See, for example, P. Kenneth Komoski, "Educational Computing: The Burden of Insuring Quality," PHI DELTA KAPPAN (December 1984): 244-248.

8. Ibid. Also, see Gail A. Caissy, "Evaluating Educational Software: A Practitioner's Guide," PHI DELTA KAPPAN (December 1984): 249-250.

9. Joseph Weizenbaum, as quoted by Otto Friedrich, "The Computer Moves In," TIME (January 3, 1983): 24.

10. Joseph Weizenbaum, COMPUTER POWER AND HUMAN REASON (San Francisco: W.H. Freeman and Company, 1976), pp. 96-97.

11. Alfred Bork, op. cit., p. 242.

* *

FAMILY MATHEMATICS KIT

The National Council of Teachers of Mathematics has prepared an activities kit to help family members assist students in learning to use mathematics. To obtain a copy, send a self-addressed, stamped envelope to NCTM Family Activities, 1906 Association Drive, Reston, VA 22091.

* *

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* *

NATIONAL ASSESSMENT INFORMATION

The National Assessment of Educational Progress (NAEP) has conducted assessments of performance of U.S. students in several content areas for nearly 20 years. The areas included in the past mathematics, but in the future will likely include "technological literacy." For a catalog of reports available on the mathematics assessments and information on what is planned for technological literacy contact NAEP, CN 6710, Princeton, NJ 08541-6710

COMPUTERS IN THE SCHOOLS - BOON OR BOONDOGGLE?*

David Chandler
PHILADELPHIA ENQUIRER, December 12, 1984

As schools around the country rush to jump on the computer bandwagon, a backlash against this rapidly growing and expensive new educational trend is building among many educators, computer experts and psychologists.

The question, for the most part, deals not so much with whether computers have a place in schools - even the harshest critics see some potential use for them - but with how they should be used, at what grade levels they should be employed and how quickly they should be introduced.

And even the most ardent advocates of computer education acknowledge that there can be problems when computers are introduced too rapidly and with too little planning.

The debate is becoming increasingly heated and polarized, with some critics charging that computer education is about as relevant as tennis lessons, and some advocates urging schools to provide a computer for every child.

The case in favor: Computers in the classroom can create great excitement and motivation to learn among students at all grade levels. This motivational effect can be especially dramatic in the case of students with physical handicaps or learning disabilities. Advocates also say that computers can foster a healthier attitude toward learning, encouraging children to explore and discover for themselves rather than simply be fed information.

The case against: Just putting computers in a school will not automatically produce any beneficial effect. It is crucial that teachers know how to use them (and want to use them) and that adequate and appropriate software - the instructions to the computer that allow it to perform a particular task, play a game or teach a lesson - be available. Even if those conditions are met, however, some critics fear that computers will be seen as a panacea, and that the result will be to divert attention from more important problems in education.

Yet, for all the intensity of the debate, there are surprising areas of agreement. Both the advocates of greater computer use in schools and those who are alarmed by the number of computers already there seem to be allied on these points:

1. The fear that young people will be unprepared for the job market unless they become 'computer literate' is unfounded. Seymour Papert, a Massachusetts Institute of Technology computer expert who developed the widely used Logo programming language for education and is a strong advocate of using more computers in schools, says this notion is absurd. Because computer technology is advancing so rapidly, he maintains, "what children are learning today (about computers) is going to be irrelevant when they get out of schools." Others point out that, although computer will undoubtedly be pervasive, the kinds of skills needed to operate them will probable be easily acquired through on-the-job training.

2. Most of the educational software available now is terrible, with a heavy concentration on "drill and practice" programs that reduce the computer to the equivalent of a set of flash-cards aiding rote memorization. Such software gives at best only a glimmering of the

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* This article first appeared in the PHILADELPHIA ENQUIRER. It is included in this issue of the CMT because it 'fits' with the overall topic addressed in this issue of the CMT.
- MS, CCTM Editor

potential of computers in education. One agency, charged with evaluating software for the New York public schools, found only two percent of available educations programs to be useful.

3. Kids love computers. The mere presence of a computer in the classroom can create in the classroom a great deal of excitement and curiosity. Critics tend to see this as seductive, advocates to see it as motivating. Said Papert: "More important than what a child learns is the attitude toward learning. Kids do want to do it use computers. It seems to me obvious that this is valuable."

4. There is some danger that computers will widen the gap between the 'haves' and the 'have nots' in our society. Another MIT computer expert, Joseph Weisenbaum, is alarmed by the rapid proliferation of computers in schools and sees this as the central issue. He believes we must concentrate on dealing with the many inadequacies of the nation's schools today before spending money to introduce something as nonessential as computers.

Papert, on the other hand, thinks that providing enough computers in the schools we could help to narrow the widening gap between the well-off, many of of whom already have computers at home, and the poor, who do not.

"Every child should have a computer" in school, Papert said. "I don't know how it should come about, but it should be done. As a society we need to make that decision."

So far, however, there have been substantial inequalities in the way computers have been introduced. A nationwide survey this year [1984] by a Colorado company called Quality Education Data found that the number of schools with computers was significantly lower in districts with high percentage of black, Hispanic or poor people.

One of the central areas of disagreement - often unstated, but undoubtedly a major factor in many people's fears of computerization - is what effect early computer use will have on children's ways of thinking. Will it lead to a more scientific, mechanical or logical style of thought?

Weizenbaum fears that computers will lead society even further toward a mechanistic world view that he believes is already too prevalent. He said, "The dominant way of thinking in our society is already too 'scientific.' . . . Children take that in with their mother's milk. What's much more important is to show them an alternative. If it were true that working with computers teaches scientific thinking and logic, then the problem is that they get too much of that already."

But psychologist Sherry Turkle, who spent more than 100 hours observing children as they interacted with computers in several classrooms while researching her recently published, THE SECOND SELF, does not believe that computers lead people toward a particular way of thinking.

"There are many different ways of mastering it," she said. "It's like a pencil, like a Rorschach. People do it in their own style, and that's a good thing - it means people can make use of it in their own ways. All kinds of styles, not just the engineer's way of doing things."

Specifically, Turkle found that in addition to the 'hard,' linear structured style usually taught in programming classes, many students, especially girls, used a 'soft' unstructured style to construct their programs - much like a painter who dabs some paint on the canvas, then stands back to see how it looked before proceeding.

Turkle emphasizes that both approaches are valid, and both can produce useful results. In

one of the classrooms she studied, for example, the most adept 'hard' programmer (who would make an elaborate and detailed chart of a program's intended structure before even beginning to write it) found that he could learn many useful tricks and techniques by looking at programs written by the leading 'soft' programmer (who would just dive in and write a line or two, see how that worked, and then make some changes before moving on to the next line).

The structured approach has no monopoly on inventiveness or usefulnesses - a lesson well worth learning in itself, Turkle believes, and one whose relevance extends far beyond its applications to the world of computers.

One of the problems with most of today's educational software is that it is too structures to allow for these different styles, Turkle says. That's one good reason, she thinks, for teaching programming even at the earliest grade levels. "Programming gives you the choice," she said.

"I think that programming is so easy to learn. There's this big debate over whether to teach programming, but even the kids who aren't very good at it - they're doing it. I happen to think that doing some simple programming is a step into seeing the machine as your personal instrument. When you program the computer, it's yours."

Papert, too, believes that programming can be valuable even in elementary school. "I see children doing a much more sophisticated level of work doing programming that I see in other areas," he said. "They can master a very complex exercise at a very early age."

But MIT's Weizenbaum is critical of the idea of teaching programming in elementary school. One of the arguments often given for teaching programming, he says, is that it teaches children to think clearly - the same rationale that was once used for teaching Latin.

Weizenbaum disputes that notion. "The mass of students at MIT . . . are very sloppy," he says. "The idea that everybody has to think clearly in order to use computers is just wrong. Most students are very sloppy programmers."

* *

It is easier to move a cemetery in January than it is to change curriculum.
- Mary Kay Corbitt -

* *

One has to be able to count if only so that at fifty, one doesn't marry a girl of twenty.
- Maxim Gorky -

* *

Getting a computer to understand what you say is one thing,
and getting it to understand what you mean is another.
- Bill Budge -

* *

THE PLACE OF COMPUTERS IN TEACHING

Naomi R. Saleman
Boulder High School
Boulder, Colorado

This is the Information Age. More people are engaged in the handling, retrieving and use of information than in any other occupation. We have been told that computers are needed in education to prepare students to enter the Information Society. In the early eighties we were given a list of the uses of computers including drill and practice, simulation,and record keeping. Now that we have some experience ourselves for a number of years, it seems appropriate to evaluate their use. This is what I would like to do in this paper.

I will address three considerations for use of the computer in education. The first is to set the environment for the use of the computer. The second is to supplement teaching, the third is to act as a catalyst to learning and to teach how to analyze complex problems.

Both the physical and social atmosphere of the computer environment can have a significant influence on student learning. The objective is to establish an environment which maximizes individual learning and creativity. The lab must be quiet enough to allow individual thinking, but not discourage quiet discussion of ideas. Students should learn to develop a relationship that allows the computer and the mind to supplement each other - each with their own strengths and weaknesses. Students should be allowed to experiment and make "mistakes" without discouragement from peers or teacher criticism.

The physical placement of the computers is also important. Computers should be arranged to break down the structured atmosphere and maximize individual creativity. It is hard to think in a creative, problem solving manner when confronted with a structured setup of a classroom. It is advantageous to have the computers arranged so that the student becomes engrossed in his own work and is not able to see the screens of other students. Distractions are minimized this way. In general, there should be no more than two people per computer. It is essential for both people to obtain practical experience. Given an appropriate environment, computers have the capability to stimulate learning. Students don't feel threatened by the computer and yet feel the lesson is individualized.

The computer can be used to supplement teaching through demonstrations and through individual use by the student. Which way the computer is used depends also on the number of computers available.

There are certainly times when a lecture situation is the most effective use of the computer. In Algebra, for example, the graphing of various equations is very helpful. Students learn by observing how the various coefficients affect the shape of curves and in turn become more proficient in identifying the graph. Data could be used to create various graphs and curve fitting could be used to find the actual equation of the curve. Students have difficulty applying the mathematics they learn to practical courses like Physics. With practice in taking actual data and plotting it and using the curve fitting techniques, the tie between mathematics and science is strengthened.

Software is the key to effective use of the computer. More and more software is being developed to meet the needs of educators. Computer programs are available that develop estimation skills. Statistical analysis can be taught by using spread sheets and the possibility of using real life data is much more meaningful. Some things are better taught by other methods other than the computer. Don't use the computer just because it is the thing to do. Make sure that you check out the software before using it with a class.

Geometry is another subject where computers can effectively supplement teaching. The section on projections can be very effectively taught using the computer. Different figures can be presented on the screen along with their projection on any plane. This is a very difficult concept to visualize on paper but can be illustrated nicely using a computer. Logo is also very useful in helping students learn the characteristics of figures, including shapes, angles, and distances.

The computer can also supplement teaching by providing help on an individual basis outside the classroom environment. The student can control the speed of learning as well as the quantity.

In addition the student can use the computer to obtain individual help after an absence from class. It is good to be able to have the lesson on the computer so that the student can make up the work at any free period and need only ask the teacher about any problems.

Unfortunately the software to solve the problem sometimes has not been developed. In fact, I think we would all agree that useful software is very hard to find.

Programming has traditionally been taught as an introduction to Computer Science. However, a more important function is to teach logic and the methods of analyzing complex problems. Geometry is generally used to teach students logical thought. Although it does teach the order of operations and applications of known truth, it does not teach modular thinking. Programming languages like Logo and Pascal teach the student to break things into smaller pieces and also allows the student to work through problems in his/her own way. The application of computer programming extends well beyond the teaching of computer languages.

The application of computers to education extends well beyond drill and practice if a creative environment is established. The computer has been well established as a supplement to teaching. However, we are just beginning to understand its use as a tool for teaching how to logically solve problems.

* *

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* *

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Interested in making your APPLESOFT program "erase itself" if someone attempts to tamper with it? Do this: insert the following line number 2 at the outset of the program.

```
2 POKE 214,244
```

Then scattered about your program insert the following command:

```
IF PEEK (214) <> 255 THEN NEW
```

Don't do this until your are finished with the program however since it will erase the program if the program is "tampered with."

Ned Schillow, in Missouri CTM NEWSLETTER, January, 1985.

* *

THE PLACE OF TECHNOLOGY IN THE TEACHING OF SCHOOL MATHEMATICS

Comments & Concerns From A School Board Member

William M. Soult*
Longmont, Colorado

The computer phenomenon has made rapid inroads into school curricula, quite often without proper school board or administrative guidance and approval. Publicity on the need for excellence in education -- and computers -- has led school officials to accept the importance of developing computer curricula before clear instructional objectives are determined. Overzealous parent groups, teachers, students, and administrators all want to be first to use computers in classrooms.

At the same time, most school officials lack knowledge on how to implement these programs and they readily accept the advice of sales people, parents, teachers, and any other purveyors of information. Further, a plethora of educational computer journals has emerged, all with expert advice. And as could be expected, the results are chaotic. Parent and other school advisory groups donate computers and software so their children don't fall behind. Teachers debate the merits of hardware and software based solely on their personal preferences or on finely tuned sales presentations. School boards mandate implementation of computer science courses before teachers are trained to teach them.

In any school system, the microcomputer should be a hard-working tool, a source of power that helps teachers, administrators and students achieve existing curriculum goals. They (computers) should not be used as an end in themselves, but rather as a tool to achieve curriculum goals. The administrators, teachers and students shouldn't become so dazzled with the technology that they allow them to become showpieces that never do any real work. The best way to make sure that the microcomputer is put to good use in your schools is through appropriate inservice training - by teaching the teachers to understand how the machine can work for them. As a board member, I sometimes have the opportunity to visit schools and observe the use of computers in the classroom. I'm sad to say that in most cases, the computer is considered by the teacher as an add on requirement, not as a powerful tool that can reduce the time spent on the current requirements of the class.

If the vast majority of accounting and engineering calculations in industry today are performed by computers, then why don't we teach our kids how to use computers to perform accounting and scientific calculations, and to become comfortable with computer listings of these calculations.

I have observed resistance to the use of the computer in the classroom by those teachers that don't understand the potential of this administrative tool. One business teacher recently told me that there wasn't enough time to introduce computers into his accounting class because he required the students to complete two practice sets. I asked him why he didn't use the computer to solve the practice sets so that the class could possibly complete four or five practice sets instead of the current two. His response, "I am a firm believer in the basics; I want my students to know how the calculations are made."

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* [Editor's comment: Mr. Soult is currently a systems programmer at IBM and member (8 years) of the St. Vrain Valley School District, Board of Education, president of the Colorado Association of School Boards, and chair of the CDE Project Renaissance Mathematics Task Force. He is formerly a mathematics and physics teacher (7 years).]

Microcomputers are just a means, albeit a powerful one, to help students learn what your school system already has decided they should learn. We must make sure that the use of computer technology serves the curriculum and doesn't flourish for its own sake.

In general, precollege mathematics, and I would also add, science, business and social studies instruction, has yet to take advantage of advances that have occurred in technology during the past few years. In view of the widespread acceptance of computers throughout the U.S. society, and our continuing progression toward an information society, an immense opportunity exists to develop curricula and instructional approaches that can motivate larger numbers of students and increase the flexibility of solution alternatives to the problems available to them.

One of the real puzzlements of education today is the fact that on one hand we have parents, students, teachers, administrators and board members clamoring for the inclusion of computers into the curriculum, but very few if any of these same people use the computer in their daily activities, when they have every opportunity to do so.

The teaching of computer literacy is an essential in today's world, but computer literacy is computer literacy, and not computer programming. We are only kidding ourselves, as educators, if we mandate computer literacy in our curriculum and then don't avail ourselves of the tremendous capability of the microcomputer as an administrative tool.

Applications of calculators, computers and other electronic information technology are reshaping the fundamental methods of doing and teaching mathematics. Applications of these same capabilities to instruction should be bringing major changes to mathematics classrooms and to the roles of mathematics teachers.

One major influence of technology on mathematics education could be its potential to shift the focus of instruction from an emphasis on manipulative skills to an emphasis on developing concepts, relationships, structures and problem solving skills. Traditional precollege mathematics curricula have stressed the development of a variety of mechanical procedures. The use of calculators and computers as standard tools in quantitative problem solving situations, however, has already diminished, and should continue to diminish the value of human proficiency in the execution of such procedures. Much of the instructional time currently devoted to acquiring proficiency with paper and pencil algorithms must, and should be, reallocated to support a range of new or previously neglected topics.

The widespread availability of calculators and computers, and the increasing reliance of our economy on information processing and information transfer are significantly changing the ways in which mathematics is used in our society today. All high school graduates need to achieve a certain level of literacy in mathematics in order to deal with everyday life. This level is continually increasing as life becomes more complex. The use of calculators and computers must be integrated into the total school curriculum and not just into the mathematics curriculum.

Fairly substantial changes in emphasis, though not in overall content, in elementary and secondary school mathematics is needed. Drill and homework are essential, but problem solving must be the focus of school mathematics. The concept of basic skills must encompass more than computational facility. Beginning in the earliest primary grades, students and teachers should actively develop and analyze the content and nature of mathematics. This requires changes in the roles of both teachers and students. The teacher's primary role will change from that of a presenter of knowledge (how to perform a certain operation) to that of a guide who uses class discussions and other experiences to encourage students to devise, test and improve their mathematical ideas and insights. The student's role will change from that of a receiver of

knowledge (mastering algorithms; producing final answers) to that of an active learner who constructs useful mathematical understanding and develops effective techniques for solving mathematical problems.

What better way to achieve this changing role of both the teacher and the student than to use a readily available and powerful administrative tool. This machine can perform many, many calculations of "possible" solutions to the problem, thus allowing the teacher to coach the student, and allowing the student to think his or her way through the problem. Again the key is that the computer is, and must remain, only a tool to achieve these curriculum goals, the computer is not the curriculum.

Finally, both teacher inservice and teacher education programs must be modified to reflect these changes in school mathematics content and to model the delivery of instruction through appropriate applications of technology. This revised thinking in instructional delivery will play a major role in the improvement of mathematical instruction, brought about by the proper placement of technology in the classroom.

BIBLIOGRAPHY

"Math Task Force Report," CDE Project Renaissance, August 1983

"Updating School Board Policies," Educational Policies Serviced, NSBA, Vol. 16-1, January 1985

"In-Service Training Puts The Ox Before the Plow," AMERICAN SCHOOL BOARD JOURNAL, March 1985

"The Condition of Precollege Education in Mathematics, Science and Technology," National Science Board, June 1982

"The Impact of Computing "Technology on School Mathematics," Report of a NCTM Conference

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HIRES 'CALLing'

The APPLESOFT command CALL 62450 sets the color of the Apple high resolution graphics screen immediately to black. CALL 62454 sets the full HIRES screen to whatever HIRES color was last specified.

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EDUCATIONAL R & D REPORT is a periodical report of activities at the Central Mid-Western Regional Educational Laboratory (CEMREL). It gives brief reports and announcements of interest to those involved in teaching. For information contact R&D Interpretation Service, CEMREL, Inc., 3120 59th Street, St. Louis, MO 63139.

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COMAP NEWSLETTER AVAILABLE

The Consortium for Mathematics and Its Applications (COMAP) publishes a newsletter of interest to all mathematics teachers, at all grade levels. It is available free (I think) from COMAP, 271 Lincoln Street, Suite #4, Lexington, MA 02173

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OPPORTUNITY IS KNOCKING - WILL WE RESPOND?

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The search for tools to help make life easier and more enjoyable has occupied man for eons. Some tools have had a major impact on people. Try to imagine life, as we know it today, without the wheel, cars, airplanes, the printed page, etc. The impact of these "tools" on society is indeed far-reaching.

Today we are living with a tool that is as pervasive as the wheel, although it is much more complex in design. At times we struggle with "how best to use it," yet few would deny its impact on society and the anticipated future impact that this tool may have for us. We find the computer in many businesses performing an assortment of tasks for us. Computers help us to keep track of numbers and names, equations and formulas, and all kinds of data. Computers help our cars to run efficiently, planes to fly on course, trains to avoid each other. Computers interface with people and other tools to help make life more enjoyable and in many ways more complex.

How do we as educators deal with this tool? Do we use it or do we ignore it? If we use it, why should we use it, how should we use it and where do we use it? We cannot be content to sit and wait for these questions to be answered. Decisions must be made and action plans put into place.

The media and a host of people in business and industry are telling educators that they must use the tool and teach students on its use. The issue of computer literacy has forged downward from colleges and universities to high schools , middle schools and elementary schools. Articles have begun to appear in the mass media on the use of computers with pre-school age children. There is even an international flavor to the issues concerning the educational use of computing technology. Articles about the expanded use of technology in education in Great Britain, France, the USSR and other countries are having an impact on American education. The competition for trained technologists is hitting hard at home and abroad. The global impact of this new tool is hard to miss. It is ludicrous to think we can avoid making decisions on technology use in the curriculum.

Before we address these issues on the use of technology, let us review the history of several other tools and how their use evolved over time. When the automobile was first invented, only the inventors, the mechanics used them. As time went on, more and more people discovered that they didn't have to become mechanics in order to drive the automobile. With mass production, not only could the automobile be produced, but parts could be mass produced and numerous side industries sprang up to support the non-mechanically inclined automobile owner. Today, many people from all over the world drive the automobile. The majority of these people cannot explain how the automobile works nor can they fix it when it fails to work. These people rely on the tool and use it very well to support their day-to-day transportation needs in spite of these shortcomings.

The phonograph is another marvelous tool whose history is important. When the phonograph was first invented, it was used to record family get-togethers, Aunt Bess's piano recital and family singing. Enrico Caruso and John Phillip Sousa changed all of that. Pre-recorded records of Caruso and Sousa brought a new use of the tool into the homes of many. People could play great music even if they couldn't create good music. In fact, the tool became a playback only device; most record players do not allow you to record your own voice and conversations.

If we review what has taken place in our mathematics curriculum over the past 10-15 years, we find that the first users of the computer were involved in programming. Only the "mechanics" have been driving the technology. Today, that is changing. Software has become for the computer what Caruso's records were for the phonograph. Many people can now use the tool without having to "make the music" themselves. And as occurred with the automobile, "non-mechanics" now own and "drive" the computer.

The question is "How should we use the tool?" not "Should we use it?" We should guide its use in mathematics curriculum. The National Council of Teachers of Mathematics recently published a report titled "THE IMPACT OF COMPUTING TECHNOLOGY ON SCHOOL MATHEMATICS." In that report, the authors stated "The major influence of technology on mathematics education is its potential to shift the focus of instruction from an emphasis on manipulative skills to an emphasis on developing concepts, relationships, structures, and problem-solving skills." This statement reminds me of a statement made by the late Dr. Julius Hlavaty, a Past-President of the NCTM, and dedicated educator. Dr. Hlavaty spoke out at a workshop I was giving on technology in 1976 with Dr. Ruth Hoffman, and stated that "for years I have thought that we have spent the majority of our time in the mathematics classroom teaching algorithmic processes. Monkeys can learn algorithmic processes, we should be spending more time on the human skills of problem solving and analysis. Today we have tools that can help move us away from spending so much time on the "sub-human" skills and can spend time teaching children the more "human skills." Dr. Hlavaty was a gifted individual. His insights then are important for us to consider now.

Do we continue to promote the idea that computers are to be used only by the students who are interested in becoming "mechanics" or programmers, or do we challenge ourselves to explore how we can best use the computer to help students develop concepts, relationships, structures, and problem-solving skills? The majority of the effort devoted to computing in the schools seems to be spent on students learning how to program the tool and make their own "music." It's difficult to find time and money for hardware, software and teacher training on the use of technology in the classroom for purposes other than the teaching of programming skills. The few teachers, administrators and parents who are involved in these other tasks stand out like an oasis in the desert.

There is a challenge to teachers (mathematics teachers in particular), at all levels, to begin to look at how best to use this "ubiquitous" tool. Explore the curriculum and discover again those areas in the mathematics curriculum which emphasize developing concepts, relationships, structures, and problem-solving skills. There is software that can help students at all levels to build those "human skills" to which Dr. Hlavaty referred. Curriculum should be reconceived. The NCTM in "An Agenda for Action" recommended that "problem solving be the focus of school mathematics in the 1980's" and that "basic skills in mathematics be defined to encompass more than computational facility." They further recommended that we take advantage of the power of calculators and computers at all grade levels.

The opportunity is here for teachers, administrators and parents to work together to provide the tools which teachers today need if they are to effectively prepare students for a changing world. Thinking should be expanded on how computers should be used in the curriculum. The tools must then be provided where they are needed. The task includes more than preparing "mechanics" for the future. Students must be prepared to be problem solvers and critical thinkers. We cannot be content with a curriculum that spends most of its time on rote learning. While that remains important, we must encourage thinking which emphasizes problem solving and allows students to play "what if" games. The task ahead is not an easy one. There are risks to be taken and most certainly much time to be spent if we are to educate students for the world of the future.

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SCHOOL MATHEMATICS AND THE PROMISE OF COMPUTING

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With doubts about so many facets of life in the 1980's, of one component there is general agreement: influence of high technology is all around us and will be for years to come. In banks with automatic teller machines, in grocery markets with universal product code readers, and in telephone booths with credit card slots we find the electromagnetic enhancement of the way we conduct our affairs. Medicine shows the influence with such new treatments as computer assisted neurosurgery to locate brain tumors and "vaporize" them (GREELEY TRIBUNE, 1985) and with the pioneering Eyescan device that opens two-way communication to profoundly paralyzed patients (THE CHRONICLE OF HIGHER EDUCATION, 1985). Feeling the thrust of this industry, educators face the challenge of using the technology wisely and creatively to complement the processes of education, making them more effective and appropriate. We mathematics educators will set the pace.

In the past, accomplishments in technology have outstripped educators' preparedness to use sophisticated new products. Ernest Boyer (1984) underscored this point with references to educational television. "Seasame Street" is a notable exception to the general failure of television programs' taking root as vital contributors in children's education. With respect to personal computers, robots, tantalizing peripherals, and associated software, educators must use exceptional discrimination. The industry is ahead of the profession, now as formerly. Much of the software on the market is overrated, and even high quality material is only suitable if it meshes with particular classroom, school, or district needs. Hardware, we must remember, is only really as useful as the available software. Just imagine, for example, how unfriendly a Macintosh can be without MacPaint, MacWrite, and a mouse! With the latter, Macintosh is a tool powerful enough to help us do our jobs more productively and more creatively. Without them, it is a powerful device only in the hands of an elite cadre of "hackers".

Most of us in education--and in society at large--are not equipped with sufficient programming skills to make much use of the hardware alone. If most of us had to rely on our own talent to supplement our classroom options with computer assisted instruction, complete with high motivation graphics, and the like, the hardware would just sit idle and gather longing glances. Not many of us would write word processing routines to use with our students or to help us with essays, production of classroom materials, and memos. Only a few of us in mathematics would develop sophisticated courseware to do more than drill and practice. Software of top caliber is the key to unlocking the potential of this technology in schools. Software is the key in utilizing personal computing in mathematics, just as it is in the other subject matter groups. In 1960, the money spent in computing went 80 percent to hardware and 20 percent to software. Today, it is just the reverse (Poirot, Norris, and Hammons, 1985), an arrangement that demonstrates the budget attraction of software. Informed and discriminating consumers are a professional necessity.

Sometimes excellent programs do really stand out. THE FACTORY, from Sunburst Communications is one such example that teachers can choose to give students experiences in geometry. This program creates three kinds of machines: hole punching, striping, and rotating. Students can apply any combination up to eight of these machines to transform pieces of raw material that look like unadorned squares (see Figure 1 on following page) into finished products that have various holes and stripes and a specific orientation. The following steps create the end product shown in Figure 1: Rotate 45, Stripe thick, Rotate 90, Stripe thin, Punch two circular holes, and Rotate 90. Students can be ingenious as they have

EXAMPLE FROM THE FACTORY

FIGURE 1

experiences in spatial visualization and sequence of instructions. They can challenge themselves or one another to develop a factory that produces a given result. Thus, the program invites problem solving. Students can even explore efficiency of instruction steps; the above six statements can be reduced to five that still make the same finished product. A program like this one is excellent to me for a number of reasons. THE FACTORY meets or exceeds my minimum technical requirements for courseware and even more to its credit reflects two qualities of many admirable mathematics lessons, regardless of the delivery mode. I want to focus on its promoting "drill and practice at the problem solving level" (Wirtz, 1974) and on its featuring "low-entry and high-ceiling" characteristics.

First, students might use over and over their knowledge of rotation and degrees, computation, squareness, symmetry and asymmetry, and the like. Drill and practice with these ideas, however, is not an end in itself. If problem solving is confronting perplexing situations for which one does not have an algorithm, then the products with which THE FACTORY challenges most students create problem solving situations. To interact with the program, students use various levels of analysis, logic, and spatial visualization.

Second, the "low-entry and high-ceiling" feature is apparent, initially, in the ease with which one can get involved with the program by playing with each machine alone and then in combination. Using several machines in concert with each other, the high-ceiling feature is evident. Students can intellectually soar with THE FACTORY. Complex figures that demand coordination of machines and a careful sequencing of them challenge students to use their abilities in the keenest ways. The quality that enables students to interact with a project with no difficulty is "low-entry", and the quality that entices them to investigate the project to the limit of their abilities is "high-ceiling". (I believe I first encountered this phrase in connection with LOGO.) Teachers might lead students to "soar" mathematically with such questions as these:

1. What happens if you interchange two instructions?

2. What are some products that are possible with an eight machine factory that are impossible with a six machine factory?

3. Think of a new machine. Draw some products you could make with it.

4. Make some figures with just one line of symmetry.

Students can conduct an endless variety of investigations that span the ingenuity of the class and teacher. A first-time user can interact easily with this program and can soar with it depending on widely varying intellectual abilities and creativity. Not all software offers this capability.

THE FACTORY, however, permits, but does not suggest, such inquiries as the four above. The opportunity is there, of course, for students to leap into that kind of mathematical exploration; some teachers will point the direction, but the move is not part of the software. Certainly, no software can be expected to do everything, but some software needs to launch youngsters into mathematical realms vastly different from typical arithmetic and geometry exercises that form the basis of the haunting stereotypical images of mathematics as dull, deadening, and difficult. If youths experience mathematics as "a search for relationships that are not obvious" (Wirtz, 1974), as a lively and invigorating process, then the stereotype of mathematics will be far out of sync with the encounters youngsters have with it. At a time of crisis in mathematics education, to offer exciting mathematical inquiries may be more important than ever, and computers provide an ideal medium for such activities.

Take as an example the problem of "The Tower of Hanoi". The job is to move the stack of disks from one post to either of the other two posts according to two simple rules:

1). Move disks one at a time, and
2). Never place a larger disk on a smaller one.

TOWER OF HANOI

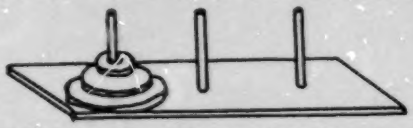

FIGURE 2

Software could help youngsters get into this problem, which features low-entry and high-ceiling. It could encourage children to play with an actual hands-on device to familiarize themselves with the rules and the material. They could maneuver a screen version of the Tower of Hanoi in conjunction with their moves on the hand-held apparatus, and the software could give guidance and feedback according to the youngsters' levels of performance. For the most sophisticated minds, the program could point the direction from collection and organization of data all the way to summary of the data in algebraic terms. In other words, youngsters could encounter the problem for one disk, two disks, three disks, etc., gathering and organizing data and pressing toward a general statement for the minimum number of moves for any given starting number of disks ("n" disks).

An abstract algebraic generalization, however, is not an appropriate objective for most students. Experiencing processes of problem solving, however, is a defensible goal for all students, and the extent of the pursuit into abstraction depends on individual abilities and interests. I, for one, have enjoyed the Tower of Hanoi since the time I was a second grader, which was years before I handled abstract generalizations. My parents gave me the apparatus and helped me understand the rules. I developed a "kinesthetic type" of generalization that enabled me to resolve the situation for any number of disks that would actually fit on a post, eight of them, I believe. Remembering a little mnemonic, "even off and odd on", I always knew where to place the first disk; so, I could always satisfy myself and amaze peers and grown-ups with swift solutions. Even today when I actually work this problem with my hands, I recall the mnemonic.

What I propose, though, in this computer age is software that facilitates and invites exploration of mathematical situations like those of mine with the Tower of Hanoi, that have high probability of appealing to school-age learners throughout the grades, that have low-entry and high-ceiling characteristics. I am advocating software that opens to students a cross

between a mathematical museum and a mathematical playground. I am advocating highly interactive software that is keenly responsive to students' performances. I want the kinds of programs that promote "open discovery" and "guided discovery", that heighten students' processes of problem solving.

The software must also provoke flexibility of thinking. It can lead students at appropriate junctures to investigate alterations of given problems, thus assisting them to treat an initial situation as just one of many. For example, the Tower of Hanoi involves three posts as stated, but inquirers could consider the situation for four, five, or more posts. Software could encourage youngsters to change other variables in this problem, and thus, to pose and explore new, derived situations. Brown and Walter (1983) present this approach for non-computer settings; Wirtz (1974) envisioned a component like this one in the learning of mathematics in schools. The technology to bring such an approach to classrooms now exists. Such situations invariably present drill and practice at the problem solving level. Thus, teachers will find stimulating new ways to enable youngsters to tackle traditional curriculum objectives.

After all, teachers and students live with real district and public concerns and, therefore, with specific content objectives. All of us must view software with these factors in mind, but we must resist the limits they imply. If we resist, then our students are more likely to encounter mathematics in a more exciting fashion than the traditional one. If problem solving is our number one goal (NCTM, 1980) as professional mathematics educators, then the approaches offered here advance that aim. Moreover, they suggest synthesis of the technology, community and district concerns over "basics", and the promotion of mathematics as a dynamic and vital process. Let us dedicate our efforts to ingenious incorporation of computing into school mathematics. Less fervor on our parts will only lead to a shriveling of the possibilities that stretch before us.

REFERENCES

Boyer, Ernest L. Education's new challenge. PERSONAL COMPUTING 8,9 (Sept 1984): 81-85.

Brown, Stephen I. and Walter, Marion I. THE ART OF PROBLEM POSING. Philadelphia, PA: The Franklin Institute Press, 1983.

THE CHRONICLE OF HIGHER EDUCATION. New device enables victims of paralysis to communicate. 29,20 (Jan 30, 1985): 6.

GREELEY TRIBUNE. Computers pinpointing brain tumors. (Jan 13, 1985): A-6.

National Council of Teachers of Mathematics. AN AGENDA FOR ACTION: RECOMMENDATIONS FOR SCHOOL MATHEMATICS OF THE 1980s. Reston, VA: National Council of Teachers of Mathematics, 1980.

Poirot, James; Norris, Cathleen; and Hammons, Charles. Ada--A new programming challenge. THE COMPUTING TEACHER 12,4 (Dec/Jan 1984-1985): 60-65.

Wirtz, Robert W. MATHEMATICS FOR EVERYONE. Washington, DC: Curriculum Development Associates, 1974.

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THE IMPACT OF COMPUTING ON THE MATHEMATICS CURRICULUM

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In the foreword to COMPUTERS IN TEACHING MATHEMATICS, Peter Kelman writes:

> "The computer is a rich and complex tool that is increasingly within the financial means of schools. Like any educational tool, it comes with inherent advantages and disadvantages, is more appropriate for some use than others, and is neither the answer to all our educational ills nor the end of all that is great and good in our educational system. Like any tool, it can be used well or poorly, be overemphasized or ignored, and it depends on the human qualities of the wielder for its effectiveness."

I don't believe that we can accept all of the options Kelman states. That the computer can be used well or poorly is true; overemphasized, certainly; ignored, never! As pervasive as books are in the hands of each of us, so too, in the words of Seymour Papert (author of MINDSTORMS), the computer will become as a pencil in the hands of a child. The significant question of course is how long before Papert's vision becomes a reality and what is the relevance of such capability? In his most recent book, PREVIEWS AND PREMISES, Alvin Toffler emphasizes that we must graduate individuals who are knowledgeable, literate, resourceful, empathic, and innovative. Furthermore, the development of higher level and generalizable skills are essential for students who will probably change careers and specialities a number of times in their lifetime.

Shortly before her death, Margaret Mead observed that we are in an age where no one will live in the world into which they were born and no one will die in the world into which they worked in their maturity. In a similar way, John Naisbitt, whose best selling work MEGATRENDS cast him into the role of a global guru, challenges us to re-invent the world we live in, to reconceptualize. As math educators, to reconceptualize our role requires revising our methods of teaching mathematics or be classified by anthropologists as a 20th century dinosaur.

Numerous articles and studies, professional organizations and associations, government and institutes have called for a plan of action for improving mathematics in a technological age. The theme for the 63rd Annual Meeting of the National Council of Teachers of Mathematics (NCTM, 1985), Exploring Curriculum Alternatives, focuses a direction for considering relevant skills for students, most of whom will be living their life-time in an information society. Lest we become extinct, math educators must contribute significantly toward promoting changes in the mathematics curriculum and provide adequate preparation for a future confronting their students. We cannot ignore the place of technology in the teaching of mathematics, and the use of computers represents a small but significant subset of the technological universe. For many, however, the term technology in education only implies teaching about computers in the schools; however in an information society the powerful capability of the computer and its diverse uses cannot be neglected. This article, therefore, will focus on the place of computers in the teaching of mathematics.

One of the most important skills we need to cultivate is the skill of learning new things. Teachers of mathematics must promote the learning of concepts, relationships, structures, and problem-solving in new ways. Computational skills, which have dominated the K-12 mathematics curriculum, are more appropriately handled by using calculators and computers. The emphasis now must be on mental operations to obtain quick approximations. Let us use calculators as tools for one-time computations, and computers as tools for the repetitive calculations and executions of numerical and symbolic manipulative procedures which students now spend countless hours mastering. It is imperative that teachers of mathematics spend their instructional time using

the computer as a tool to enrich their student's understanding of mathematics and strive to eliminate the many practices where mathematics courses are directed toward the use of the computer as an "object" rather than as a tool. They must also declare to their colleagues and administrators that as "mathematics teachers" they are no longer the unofficial computer science instructor for the entire school! Slowly, we are observing that teachers within other disciplines are rightfully assuming the responsibility for teaching the courses in "computer literacy".

In March of 1984, NCTM and the Center for Mathematics Education of the University of Maryland, with financial support provided by the National Science Foundation, sponsored a conference to consider "The Impact of Computing on School Mathematics." From that conference came many recommendations only a few of which are mentioned here.

A broadened view of mathematics appropriate for grades K-4 was urged.

Because computers and calculators can be used effectively in teaching mathematical concepts, no a priori assumptions should be made about the appropriateness of any given mathematical topic for elementary students. For instance, decimals, negative numbers, and scientific notation appear naturally when using calculators and can be taught as they arise. Computers facilitate an early introduction to geometric concepts such as transformations, congruence, and vectors; statistical concepts such as randomness; and algebraic concepts such as variable and function.

Preparing activities and simple computer programming in Logo and BASIC can be done by students as early as the kindergarten level to convey both mathematical and computer concepts. Computer literacy should come as a natural by-product of such experiences rather than as a special addition to the elementary school curriculum. (Emphasis mine)

This indeed requires dramatic changes in the manner of thinking about mathematics by elementary teachers. It also implies that a more rigorous understanding of mathematics be required of the preservice teacher and inservice programs be implemented which can update the mathematical competencies of present practitioners.

Consider some of the recommendations for the middle school level, grades 5-8.

Mathematics in the middle grades should emphasize the development of "number sense"-the intuitive feeling for the relative sizes of numbers that is essential in skillful estimation, approximation, mental arithmetic, and the interpretation of results for reasonableness.

By the end of grade 6, students should be able to write simple computer programs that require looping and branching concepts. The emphasis in such programming activities should be on problems that convey significant mathematical ideas.

Those who have the responsibility for developing senior high school mathematics curricula must be especially cognizant of the changing college and work environments their graduates will enter.

The selection and sequencing of high school mathematics for college-bound students should no longer be governed solely by preparation for calculus. The most important mathematics for many students will consist of topics from discrete mathematics and statistics. High school programs must reflect these goals in their content and priorities.

For high school students with limited ability or interest in mathematics, technology offers

an opportunity to enrich curricula with realistic problem-solving situations without insisting on a mastery of skill prerequisites. These students can concentrate on skills necessary for collecting, organizing, interpreting mathematical information; skills appropriate for estimation and approximation, problem-solving strategies, data analysis methods, and reasoned evaluation of results.

These are only a few among many very specific recommendations emerging from this conference. The fundamental theme throughout these recommendations implies a new relationship among teachers, students, and the subject matter. The presence of computers and calculators creates a new classroom dynamic in which teachers and students become partners in the search for an understanding of mathematical ideas and the solutions of mathematical problems. Certainly new roles for classroom teachers and students are being made possible. There are problems of course as we move into this new era. Inadequate software, a lack of teacher training, insufficient hardware, equity issues and the inevitable changes to come in the structure of education are significant obstacles and cannot be solved overnight. Presently, there appears to be many more problems than solutions. To resolve these classroom teachers must become involved in the issues of evaluation and effectively form partnerships with the educational researchers in testing the appropriateness of these new programs and the impact of the technology upon achievement, attitudes, and attainment of useful skills. The well-educated, committed teachers of mathematics will be the key to the successful implementation of these curricular and instructional improvements and enable the nation to move toward the educational excellence everyone desires.

Kelman aptly described the computer as a rich and complex tool. Let us use it well.

REFERENCES

Kelman, Peter and others. COMPUTERS IN TEACHING MATHEMATICS, Reading, Mass.: Addison-Wesley Publishing Co., 1983.

National Council of Teachers of Mathematics. THE IMPACT OF COMPUTING TECHNOLOGY ON SCHOOL MATHEMATICS : REPORT OF AN NCTM CONFERENCE. Reston, Virginia, The Council, 1984.

Papert, Seymour. MINDSTORMS. New York: Basic Books, 1980.

Toffler, Alvin. PREVIEWS AND PREMISES. New York: William Morrow Co., 1983.

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MODEL ROCKET UNIT AVAILABLE

A unit on model rockets for 11 and 12th grade students might give your class a boost (UGH!). The unit was developed by Laura Reeves of Albuquerque with funding from the NCTM Mathematics Education Trust. The 28 page unit titled MODEL ROCKET MATH is for about two weeks of instruction and includes making and launching rockets, analyzing flight and the mathematics related to rocketry. It costs $4.00 (prepaid) from NCTM, Dept. E, 1906 Association Drive, Reston, VA 22091.

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A SYSTEMS VIEW OF TECHNOLOGY IN THE TEACHING SCHOOL MATHEMATICS

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In 1983, The National Science Board Commission on Pre-College Education in Mathematics, Science, and Technology issued a report entitled, Educating Americans for the 21st Century. [7] The first four chapters of the report address the teaching and learning of mathematics, science, and technology in grades K-12. The issues of appropriate content and process are discussed as are suggestions for the revision of content in mathematics and science of the traditional elementary and secondary curriculum. The Commission expresses the hope that

> "--the ideas expressed in this Volume will aid those actively involved in the improvement of elementary and secondary education and motivate others within their appropriate roles to bring this country's educational system to the forefront in the world by the year 1995." [7, p. iii]

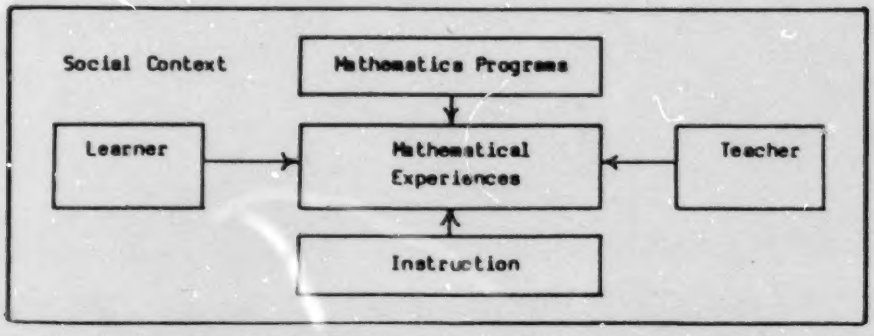
What is evident throughout this report and the NCTM Report, The Impact of Computing Technology On School Mathematics [6] is a need for curriculum revision predicated on the fact that computing technology can and will be implemented in this revision. Indeed, the authors of the 1984 NCTM Yearbook Computers in Education state in the preface that "the computer is definitely here to stay in education, both in the classroom and in the home," and "the integration of the computer into the curriculum is at best in its infancy." [5, p. ix]

This paper will be concerned with the impact of computing technology on mathematics curriculum revision. A systems approach to curriculum revision will be presented and relevant questions posed.

Mathematics Curriculum Revision

Walter Dick wrote in 1975 that when one considers the role of educational technology in curriculum revision, a systems approach to revision has considerable merit. [1, p. 71] Dick states that a systems approach is a specific set of suggested procedures which might be utilized in conceptualizing, developing, implementing, and evaluating a new curriculum. [1, p. 73]

Thomas Romberg and M. Vere De Vault proposed a curriculum model which emphasized the interaction of four basic elements when one considers the mathematics experiences of learners. [4, p. 96] The four components are mathematics programs, learners, teachers, and instruction. The interaction of these elements is suggested below:



An examination of the place of technology in each of these components appears appropriate

since, under a systems approach, each component contributes to the total mathematical experiences which result from this interaction of elements.

Technology and Mathematics Programs

Mathematics programs are described in terms of goals, content, and behavioral objectives. Goals are statements of intent which give direction and meaning to both the choice of content and the statements of desired outcomes.

What are the goals of a technologically enriched curriculum? Are they utilitarian, stated in terms of the importance of mathematics and technology to the learner, or are they cultural, stated in terms of the importance of understanding the spirit of mathematics and technology? Are they societal where the importance lies in terms of the needs of society? Answers to these and other questions regarding curriculum goals are prerequisite to the discussion of curriculum change.

Content change recommendations for such a curriculum abound. [2,5,6,7] The NCTM recommendations deal with the topics of computation, concepts, estimation, numeration, problem-solving, computer literacy, approximation, discrete mathematics, probability, and statistics. Fey et. al. put further recommendations for change in algebra, geometry, calculus, and discrete mathematics. [2]

NCTM makes the statement:

> "The major influence of technology in mathematics education is its potential to shift the focus of instruction from an emphasis on manipulative skills to a emphasis on developing concepts, relationships, structures, and problem-solving skills." [5]

The question naturally arises: should this shift take place and if so, how is it to be carried out in a revised curriculum? What paper and pencil algorithms should be be abandoned because of the presence of calculating devices? What should the concepts/skills/applications balance be? Fey points out:

> "After admitting that there is a need to do better with problem-solving and that computers diminish the importance of technical skill, most teachers [surveyed by Fey] express serious reservations about curtailing skills objectives of current courses. But more important is the uneasy skepticism that can be dissolved only by powerful evidence that changes will cause students no harm." [12, p. 92]

Technology and The Learner

The second system component, the learner variable, has been researched with worthwhile information developed. The nature and the quality of the mathematical experiences of learners in the classroom are influenced by both cognitive and affective behaviors. The learner's developmental level, his intellectual power, his learning style, and his past mathematical experience and learning determine the cognitive behavior of the learner. Personality, perceptions of self, and motivation affect affective behaviors.

The NCTM Report did not address the learner variable. This has to be considered a serious oversight because computers, in particular, will undoubtedly influence both the cognitive and the affective behaviors of the learner. The computer offers education the rare opportunity to personalize instruction so that learning styles are individualized. In addition, the computer becomes an instrument of motivation for the learner. One need only watch a small child engrossed in a Logo learning environment to realize that both cognitive and affective behavior

are being influenced by the computer experience.

Undoubtedly the most important question to be addressed in curriculum revision is how can we best use technology to positively influence both cognitive and affective behaviors of the learner.

Technology And the Teacher

The third component of the model is the teacher. It is equally important to consider what the teacher is as well as what the teacher does. What the teacher is involves consideration of the teacher's professional background, his self-perceived role in the classroom, and his perception of the learner and the learner's needs. [4, p. 99]

Several recommendations regarding what the teacher must be able to do in a technologically rich curriculum are posited by NCTM but the issue of what a teacher is, is completely ignored. How do we convince teachers that calculators and computers are worthwhile instructional aids and that they are capable of using them in their classroom? How do we eliminate the fear of computers that is present in many teachers? Can we convince teachers that computers offer the possibility of freeing them to do more personalized professional tasks than is presently possible in the traditional classroom?

These and other questions arise primarily from the affective domain of teachers. Research in this area is an absolute if meaningful curriculum change is to be effectuated.

Technology and Instruction

Three aspects of instruction have received wide attention in the literature: instructional tasks, instructional materials, and organizational context of instruction. Each of these merits attention in this model.

Instructional tasks are those things a teacher does to facilitate learning. These tasks include planning, teaching, assigning, diagnosing, and prescribing. NCTM states:

> "Teachers must be able to make informed curriculum decisions about the appropriate place and strategy for using technology to enhance instruction." [6]

Instructional materials include textbooks, CAI, CMI, etc. NCTM recommends:

> "Teachers must learn how dynamic visual displays made possible by computers can aid transition from concrete experience to abstract ideas." [6]

> "Teachers must become adept at interpreting and elaborating computer-based evaluation of student learning and in using information management systems that organize curriculum options and assessment data." [6]

Finally, organization context is the setting in which the mathematical experiences are to take place such as large group, small group, laboratory, etc.

The current instructional uses of microcomputers fall into three general categories: learning about computers, through computers, and with computers. [7, p. 96]

Learning about computers involves both computer literacy and the teaching of programming. NCTM recommends that each of these topic be included in both the elementary and middle school revised curriculum with Logo or BASIC used in the elementary school. Is BASIC the language to

be used also in the middle school? NCTM states:

> "By the end of grade 6, students should be able to write simple computer programs that require looping and branching concepts." [6]

Is Logo a better language than BASIC to use for looping and branching because it is procedural and recursive? Logo blends well with Pascal if Pascal is to be used as the primary secondary school programming language.

Learning through computers has been the major focus of research and development in educational computing. [7, p. 96] The major emphasis in this area has been on drill-and-practice, diagnostic testing, and question-and-answer tutorials.

There are several serious instructional concerns. Learning through the computer is a computer-controlled learning mode as compared with learning with the computer. Will poor children in our society learn under the control of the computer, while those in well-to-do areas will learn to control computers?

The least developed but most promising use of the computer is as a tool of instruction and an environment within which learning can occur. How do we build meaningful microworlds within which elements may be combined according to given rules to produce problem-solving skills? How does the teacher use the computer-induced environment effectively in instruction? Are mathematics lessons to be taught in the conventional classroom on some days and in the computer lab on others? How is the computer and its related software "plugged into" mathematics lessons? There are many, many "how to" questions that remain to be answered before the teacher can begin to use computing technology effectively.

In Conclusion

It is this author's contention that effective curriculum revision in mathematics which involves the use of computing technology, should be approached using a systems approach such as that proposed by Romberg and DeVault. The mathematical outcomes of such an approach focuses attention on extremely relevant questions regarding each of the elements of the model. It is only by recognizing and addressing these elements of the curriculum and their related questions that meaningful change can be made.

Bibliography

1. Dick, Walter. "The Role of Educational Technology in the Mathematics Curriculum," Proceedings of the Conference on the Future of Mathematics Education. Tallahassee, Florida: Florida State University, 1975.

2. Fey, James. Computing And Mathematics. Reston, Virginia: National Council of Teachers of Mathematics, 1984.

3. Fitting, Marjorie. "Using Computers in Teaching Mathematics," An Agenda For Action: 1983 Yearbook. Reston, Virginia: National Council of Teachers of Mathematics, 1983.

4. _____. Journal of Research and Development in Education: Mathematics. Athens, Georgia: University of Georgia., Vol. 1, No. 1, Fall, 1967.

5. National Council of Teachers of Mathematics. Computers in Mathematics Education: 1984 Yearbook. Reston, Virginia: National Council of Teachers of Mathematics, 1984.

6. National Council of Teachers of Mathematics. The Impact of Computing Technology On School Mathematics. Reston, Virginia: National Council of Teachers of Mathematics, 1984.

7. The NSBC on Pre-college Education in Mathematics, Science, and Technology. Educating Americans for the 21st Century: Source Material. Washington, D.C.: NSF, 1983.

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MATHEMATICS DIAGNOSTIC TEST HELPS CURRICULUM DEVELOPMENT

The results of the 1984-85 CDE Mathematics Diagnostic Examination have been returned to participating schools. These results are giving some schools insight into areas of concern that had not previously been identified. Not only do the results have implications for the individual students, but they also reveal strengths and weaknesses in a districts' curriculum and mathematics instruction.

When one set of results from a large school was examined, it was found that students had very low level of success with problems involving the use of fractions. This was true at all grade levels. Another school found that problems involving approximation caused their students difficulty. One mathematics teacher commented ". . . it seems that we are doing very well in the number concept area but were having trouble in the applied area. This is the second year that our results have indicated this problem. Perhaps we should look at that area of our curriculum." The above situations and comments are representative of what has frequently been encountered. As a result of last years test, at least one district developed a new course for seniors in order to meet student needs.

If you desire assistence in analyzing the results from your administration of the CDE Mathematics Diagnostic Examination, please contact either Ms. Chris Comins at 573-3312 or Dr. Duane Clow at 491-5145. Ms. Comins is the mathematic consultant for the Colorado Department of Education. Dr. Clow is in charge of the Mathematics Diagnostic Examination and is an Associate Professor in the Department of Mathematics at Colorado State University. There is no charge for this assistance.

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OHIO STATE UNIVERSITY - MASTER OF ARTS DEGREE FOR TEACHERS OF MATHEMATICS

The Department of Mathematics at The Ohio State University (OSU) has announced a Master of Arts Degree for teachers of mathematics that emphasizes ". . . mathematics content and its applications which is specifically designed for secondary teachers of mathematics, and for middle school teachers having secondary certification." The degree can normally be completed in two summers and the intervening academic year, but is also available through summer enrollment only. If you are interested, and can obtain a years leave of absence, the degree can be obtained with financial assistance from OSU. Some fellowships are also available for the first summer of study. If you are interested, contact Dr. James R. C. Leitzel, M.A. Coordinating Committee, Department of Mathematics, The Ohio State University, 231 West 18th Avenue, Columbus, Ohio 43210-1174, phone number (614) 422-4975.

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COMPUTER SCIENCE vs. MATHEMATICS

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Should a computer science course count in place of a mathematics course in satisfying the high school mathematics requirement? At the 1984 Annual Meeting of the National Council of Teachers of Mathematics, the delegate assembly considered this question in the form of a proposal to oppose such a substitution. The debate was lively and the vote close, evidence that there were strong opinions on both sides. The opinions, their implicit assumptions, and some related questions are worth examining.

One could easily answer the question "No." and offer several supporting arguments. First, we don't count an English or a P.E. course toward the math requirement, why count a computer science course? After all, it is a math requirement, and mathematics is not computer science. Second, mathematics is one of our most important intellectual tools, and to neglect to expose students to as much as possible of this important problem solving aid renders their education seriously deficient. Third, the greater the number of students who leave school without experiencing mathematics, the greater the likelihood of diminished public support for the study of mathematics. Fourth, computer literacy can best be achieved by integrating computer concepts and applications into the existing curriculum in various subject areas rather than replacing an existing course. Fifth, the close association between mathematics and computer science feeds the mindset that mistakenly assumes that difficulty (and anxiety) with mathematics transfers to difficulty with computers, a notion that can be a major obstacle for many teachers who wish to introduce computers into their courses. Sixth, the assumption that computer science and mathematics courses are equivalent drains resources from mathematics departments, which must furnish both capital and personnel to support computer science courses. Seventh--and this probably doesn't exhaust the list--computer scientists may consider this close association as an obstacle to establishing legitimate computer science courses taught by teachers trained primarily in computer science rather than by mathematics teachers whose main qualification is having taken a course or two about microcomputers.

With all these arguments against allowing mathematics credit for computer science, how could one possibly be in favor? What were the arguments put forth by those at the NCTM meeting who opposed the resolution? Some opposed the resolution on the grounds that it was too absolute, too close-minded. Such a categorical statement, they pointed out, implies some inaccurate assumptions about both computer courses and mathematics courses. It may well be that some computer science courses teach more mathematics than many courses designated mathematics. For instance, which is better for developing problem solving skills, a course in BASIC or a year of arithmetic drill? Which is better for teaching about manipulation of symbols? Which is more intellectually stimulating? To a large extent, one could counter, these answers depend upon the course and the teacher; but this is exactly the point raised by those who criticized the resolution. One shouldn't assume that simply because a course is titled mathematics it contains more mathematics than a course not so titled.

A related objection is that such a blanket refusal to allow substitution of computer science for mathematics may force many students into another year of mathematics when they already have acquired a strong dislike for the subject. An extra year of what these students perceive as useless drudgery could backfire to the point of debilitation. Such turned-off students might leave school with a better feeling about mathematics after taking a course that is not thought of as mathematics, yet still displays some of its applications. Once again, one ultimately must consider the specific content of the course and how it is taught before passing judgement.

The foregoing, perhaps oversimplified, presentation of opinions may not have changed any minds on this issue, and that was not its intent. Rather, I hoped to show that there are reasonable arguments on both sides, and that it is important to examine the issue from the points of view of mathematics, computer science, and students. As professionals we must resist the bureaucratic imperative to categorize and dogmatically conceptualize issues in "either or" terms. Nevertheless, idealism duly heeded , we are members of a most practical profession and so must seek a resolution to this issue, one that works.

My suggestion would be to cross credit certain computer science and mathematics courses, as is done in colleges. The mathematics faculty could examine the content of a course and decide whether or not it could be substituted for a particular mathematics course. This would retain the integrity of the mathematics requirement, as well as allow for student options. It also insures that the decision would be made by those with the most relevant knowledge, the teachers of the courses.

In today's "hype-for-high-tech" atmosphere it is easy to see how those who value mathematics would feel somewhat threatened by proposals to eliminate any mathematics from the curriculum, especially if the proposals imply a misunderstanding of the nature of mathematics, as those that equate mathematics and computer science clearly do. On the other hand, as mathematics educators we must keep the best interests of our students foremost. It is hoped that the above solution and any others proposed are sensitive to all concerned.

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EDUCATIONAL TECHNOLOGY CENTER NEWSLETTER AVAILABLE FREE

ETC TARGETS is a newsletter of the Educational Technology Center at Harvard University, and is published by Educational Testing Service. It contains information of interest to mathematics teachers, names of reports available, and is free. Contact ETC TARGETS, CN6745, Princeton, NJ 08541-6745.

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"PFS" USERS NEWSLETTER

If you are a user of the PFS family of computer software, there is a newsletter for you. It is PFS: NEWS. Either send in the users card supplied with your PFS software or contact; Software Publishing Company, 1901 Landings Drive, Mountain View, CA 94043.

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MODEL CURRICULUM STANDARDS

California State Board of Education has developed a set of "model curriculum standards" for use in the California schools. For information on how to obtain a copy contact; Mr. Walter F. Denham, Director of Mathematics Education, California State Department of Education, Sacramento, CA.

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"The only certainty is a reasonable probability." - E. H. Howe -

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USING THE COMPUTER TO DELIVER INSTRUCTION IN MATHEMATICS

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The philosophical viewpoint in some recent articles contributed by Dean's of the Engineering Colleges of Colorado (ECC), professors of mathematics (reflected in positions taken by the National Council of Teachers of Mathematics) (NCTM), and the Mathematics Task Force of the Colorado Department of Education (CDE) seems to ignore the magnificent opportunity the computer has given us. These articles generally have two suggestions:

1. High school computer instruction should be withdrawn as a mathematics credit. (It should be placed in a Computer Science Department which may or may not have mathematically trained instructors.)

2. High school mathematics classes could stress word problems and problem solving skills; however they should do so only within the context of historically pristine and pure mathematics courses.

The NEWSLETTER of the ECC (#6, November, 1983) notes that students at the universities have difficulty with "the solution of word problems, or mathematics modeling . . . (and) solving problems that involve several steps . . . (they) have difficulty developing a plan for the solution." The NEWSLETTER goes on to endorse the recommendation of the CDE Mathematics Task Force (August 1983) that "Computer Science courses are important . . . but should not count as satisfying mathematics requirements for high school graduation."

The CDE Math Task Force also recommended that "emphasis be placed on reasoning and problem solving skills. Of . . . importance is the ability to organize complicated strategies to reach decisions, designs, and solutions. Students must gain experience with . . . mathematical modeling . . . students must state the problem, recognize the assumptions and constraints, formulate mathematical expressions, find solutions and interpret results."

The implications, of course, are that programming computers (while important) is not good mathematics and that problem solving (i.e., pure mathematics) is not appropriately taught in a computer mathematics class.

Maybe it is time to take a broader view of what constitutes mathematics. No one addresses this issue better than B. A. Fusaro in the newsletter of the Mathematical Association of America (MAA) (FOCUS, Vol. 4, No. 1).

> "To understand the reception given the computer by established mathematics, it is necessary to journey back in time. The current dangerously xx period of mathematics, which is showing signs of drawing to a close, began with G. Cantor's fascinating creations (1897). Presumably mathematics could be seen as a pure creation of human thought, completely independent of the world of nature. This budding humanistic conceit was bolstered by the work of G. Frege (1884) and G. Peano (1897). The three "G's" laid the foundation for a new mathematics that came to full power after World War II, as exemplified by Bourbaki & Co. The ground floor was laid by the epic "Principia Mathematica" (1910-1913) of Whitehead and Russell, who purported to show [that] all of mathematics was reducible to an abstract, severe logic, devoid of content. Ironically, the superstructure was erected by D. Hilbert (1904, 1927), known to applied mathematicians for his 'Mathematical Physics.' The workmen were urged on by G. H. Hardy, who believed that mathematics was creative, beautiful and valuable in some sort of inverse relation to its

utility."

"Statistics rapped on the door in the 1920's, but found no WELCOME sign. In fact, it was clearly a case of DO NOT DISTURB. It went out to find a new home where it could, usually in schools of agriculture or forestry. The field of operations research, developed during World War II, also found itself unwelcome and went to departments of engineering or business and management. Step by step, mathematics alienated itself from its scientific and engineering cognates. Even classical applied mathematics came to be viewed as an aberrant or interloper. Boubaki-itis was epidemic, infecting even the pre college levels via the New Math."

"This is the situation the computer bantling faced in the 1950's. Could an electronic apparatus breach the walls of abstract formalism? The message to the babe was predictable: Go away. And so it did, to engineering and business departments, and to administrative data processing centers. Thus an extraordinary tool for numerical or constructive mathematics became only remotely or indirectly accessible to departments that could have had mainframes for the asking."

"Even today, the mathematical world seems largely unaware of this missed opportunity. So it is indeed a blessing that the mathematical maiden (to switch metaphors), through no virtue of her own, has a second chance. The second chance is the microcomputer."

Our inheritance of academic disciplines as mutually exclusive subjects is an anachronism. If mathematics can be construed as including the study of symbol manipulation according to certain rules derived from assumptions, and the application of these rules to model problems, then the syntax of a programming language and the resultant algorithms are mathematics. In fact the "emphases" recommended by the CDE Math Task Force are more easily implemented by the strategies used in teaching computer programming that in the current mathematical offerings.

Computer problems are "de facto" word problems. In fact, taken out of context, the CDE Math Task Force (with is beautiful goals) describes a computer class. A good computer assignment forces the students not only to be thorough in their analysis of a problem, but, through the uses of procedures, requires them to reduce the task to a combination of smaller tasks. The nature of the environment of the solution requires a thoughtful analysis, a requirement sometimes elusive in the "pure" mathematical approach.

In the instruction given in Knuth's text, THE ART OF COMPUTER PROGRAMMING, Volume 3, one finds the definition of a "heap."

"A file of keys, $K_1, K_2, \ldots, K_n$ is a 'heap' if $K_{j/2} > K_j$ for $1 < (j/2) < j <= N$."

How can this not be mathematics?"

At George Washington High School the Computer Mathematics class among many other things, teaches solutions to polynomials of degree n, the Simplex Tableau, Gaussian reduction techniques to solutions of n equations in n unknowns, determinants, and matrix inversions. Students build models of series and examine the concepts of convergence and divergence. They analyze data with statistics and build regression lines. Prior to the computer solutions students are shown how to reduce "big" problems into "smaller" parts [Procedures and Functions]. They are required to produce certain solutions manually, certainly an enhancement to "more formal mathematical skills." In effect they are mirroring the recommendations in the ECC NEWSLETTER.

If we take the computer out of the mathematics offerings, we loose the most magnificent motivational device mathematics has ever found. Many students are studying mathematics with

determination in order to better program the computer.

Programs students write involve functions, logic, symbol manipulation, analysis of exceptional cases, precision, documentation, generalizations, significant figures, modeling, problem solving, reading word descriptions, interpretation of results, recognition of assumptions and constraints, and the formulation of algebraically related expressions. The "emphases" paragraph, taken out of context, seems to be a call for computer programming as a mathematics course.

The reason so many mathematics teachers have started teaching programming skills is that they recognize the motivational and mathematics skills fostered by programming. It is a grass roots movement, one of Naisbitt's "megatrends."

Perhaps those professors calling for an end to computer mathematics offerings are disturbed that so many computer classes do not emphasize problem solving skills as described above. The solution to this situation is not to dismiss computer programming out of hand, but to work with high school mathematics teachers to use the computer as a vehicle that enhances these skills.

Students should be counseled to that computer mathematics is a concurrent offering with the more traditional mathematics curriculum. Students often take two humanities courses. Why not take two mathematics courses? A student who is heading for a major in engineering should never be counseled to substitute trigonometry for computer programming or vice versa. However, a budding barrister might find algorithms more beneficial than analytic geometry.

I would never argue that writing algorithms for random disk access and other less obvious mathematics is, by the description in the "emphases" quote, pure mathematics.

This micro megatrend cannot be stopped. Those who are describing a different position must join the battle lines and see what we see; a method of motivating our students to be more thorough in all aspects of their approach to a problem. The dissenters should help us use this tool more effectively, not to take it away altogether. The culture lag between the theorists and the "implementors" must end. Curricula of programs that are successful in using computers to teach mathematics should be promulgated. Effective speakers on the subject should be invited to present at conferences and school district meetings. The "good" should be emulated rather than usurping energy by haranguing the bad programs with the inevitable results reported in my opening remarks.

The designers of the new mathematics curriculum should heed the warnings of Dr. Fusaro. Include the computer. Do not dismiss it to another discipline that may not use it to enhance mathematics.

REFERENCES:

Colorado Department of Education, REPORT OF THE COLORADO DEPARTMENT OF MATHEMATICS TASK FORCE, Denver, Colorado, 1983.

Engineering Colleges of Colorado, NEWSLETTER, Volume 6, November 1983.

Knuth, THE ART OF PROGRAMMING, Volume 3.

Mathematical Association of America, FOCUS, Volume 4, Number 1, 1983, page 3.

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TWO TEACHERS FOR SISTER SARAH

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If Sarah is asked "For what values of x does $x^2 + 4x + 1$ equal zero?" she has a wide range of possible responses. Based on her response to the question, other questions can be posed which will lead her to a rational understanding the concepts involved. The two teachers for sister Sarah are limited to the understanding they bring to bear on Sarah's learning. The one teacher on her insight into Sarah's responses and selection of the follow up question. The other teacher on its bank of responses for Sarah to choose from and then the quality of the logic engineered into its branching to lead Sarah with another question. And on and on until Sarah reaches a level of independently demonstrating her ability to answer a similar question forthright.

Sarah's next learning experience is intended to provide her with a divergent learning exercise. By providing open access to Logo, Papert (8,viii) sees one teacher providing Sarah with open "play." By having her curiosity piqued, Sarah becomes captivated by the reasoning process: what makes it work and "how can I change its rules and make it follow my rules." The other teacher has a collection of intriguing puzzles which challenge Sarah not only to solve the puzzles but also to create one of her own built around the rules of those with which she "played." This teacher used the "Have you thought of this?" approach with Sarah, an equally effective approach for divergent thinking.

The prevailing mood appears to be: "Which teacher for tomorrow's student?" The issue should be: "Which role for which teacher for tomorrow's student?"

Interactive computing with the instructor on video disk giving an instructional lesson and holding while a student is queried on the ideas presented is available technology (1,108). Our Sarah can rerun the lesson if she feels the need, or she can continue with the lesson if she is satisfied with her understanding. The current limitations of this teacher appear to be the exponential growth in branching as possible responses are programmed into the lesson. Since Sarah may have a considerable lag in her background, the branching would take the lesson to another part of the video disk for background development. Or, Sarah could be making associative leaps in her learning and be capable of moving along much faster and be branched by the teacher to more synthesized based learning. The volume of programming necessary to meet this level of branching has severely limited the scope for this teacher based on what is available in the market place.

Sarah's other teacher has all sorts of insight into Sarah's responses, can take her down a "most appropriate" path in the twinkling of an eye. Yet, her other twenty-nine charges aren't in the same forest much less close to the same path as Sarah and create a level of interference which short circuits the process.

The spectrum of student abilities (even in homogeneously designed classes), the continuous change in the mathematics students will need, and the decline in available competence in the classroom are pushing us to make "best effect" changes in mathematics classrooms. Davis (2,74) defined our role best: "The verdict of our colleagues on us will count as nothing compared to the verdict of history on our civilization."

In order for us to accommodate curricular, tech, and learning technology changes, there is a need for meaningful problems which can be solved with high school level mathematics. These problems need to be high interest and lead to in-depth understanding requiring the use of

scientific calculators and computer programming. Kline (3,310) argues that mathematics is plural without clearly defined rules for its pursuit and sees it changing as man's understanding of nature matures. So our role is to capitalize on these shifts by finding where and how they modify our existing curriculum, inserting them appropriately, and provide challenging problems from these for solution.

COMAP (Consortium for Mathematics and its Applications) (4,2) has entered the high school curriculum to encourage ". . . teachers (to) incorporate contemporary uses of mathematics in the classroom" and provide ". . . instructional materials which (will) make effective use of new technologies." It is this kind of problem solving pursuit that enables us to use the discrete mathematics called for in the NCTM report (5,2) or the pre-calculus mathematics, whichever is needed at those critical points in the problem solving process.

I am hopeful that teachers will use the newsletter forum to share their finds in the "search" for good problems. It is this collection of thoughts which makes me see technology bringing a reform to the problems Sarah, circa 2000, will be assigned and not the medium which will deliver those problems and direct her progress. This as a highly viable approach is supported in the NCTM commission report (6,86) where the CUPM is quoted: ". . . mathematical modeling and associated interactive and experience-oriented approaches to teaching mathematical sciences. . . involve students in the more creative and early design aspects of problem formulation, as well as provide them with a more complete exposure to how mathematics interfaces with other activities in solving problems arising outside of mathematics itself."

So Sarah will have her two teachers. One who synthesizes, analyzes, and directs her pursuits. The other which holds the capacity to do Sarah's bidding in storing, searching, comparing, and enabling an orchestrated pursuit of Sarah's design in solving a compelling problem.

We cannot lose sight of structure, nor can we afford the luxury of keeping all of the curricular holdings of the past. The college boards can be expected to reflect these changes. ACT (7,9) describes its Mathematics Usage Test as ". . . problems that are encountered in many college courses and includes mathematical techniques typically covered in high school courses."

Perhaps we can have a bigger say in Sarah's teachers than we realize. However, it won't happen without some cooperative and thoughtful effort on the part of all of us in the profession.

REFERENCES

1. Hon, David, Interactive Training in Cardiopulmonary Resuscitation, BYTE, June 1982.

2. Davis, Robert B., THE CHANGING CURRICULUM: MATHEMATICS; ASCD, 1967.

3. Kline, Morris, MATHEMATICS THE LOSS OF CERTAINTY, Oxford Press, 1980.

4. COMAP NEWS, Number 10, Consortium for Mathematics and its Applications, March 1984.

5. National Council of Teachers of Mathematics, THE IMPACT OF COMPUTING TECHNOLOGY ON SCHOOL MATHEMATICS, NCTM, 1984

6. Fey, et al, COMPUTING AND MATHEMATICS: THE IMPACT ON SECONDARY SCHOOL CURRICULA, NCTM, 1984.

7. Hulsart, Richard, SOURCE BOOK ON PREPARATION FOR COLLEGE ADMISSIONS TESTS: ACT-PSAT-SAT; Colorado Department of Education, Denver, 1983.

8. Papert, Seymour, MINDSTORMS, Basic Books, Inc., 1980.

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TECHNOLOGY IN THE TEACHING OF ELEMENTARY SCHOOL MATHEMATICS

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My experience as the Regional Education Coordinator for Tandy Corporation has allowed me to visit many schools and talk with many teachers at all grade levels. Through my training and experience as an elementary teacher I have formed some opinions about the usefulness and effectiveness of this technology. Although there are many and varied applications of the technology in mathematics, I will address some of the most common uses: drill and practice, programming and applications.

1. Drill and Practice: For the most part, many elementary mathematics teachers use computers for drill and practice of mathematical facts and concepts. I may be one of the few persons to support this application. After all, I remember creating many "worksheets" for the students I taught. I carefully designed the problems and the practice around their ability and intended development. Then I just as carefully, corrected these worksheets and recorded the grades or scores in my "teacher's book." I used these scores for creating grades at report card time and for discussing the student's progress with the parents.

   In most instances, children need time to practice what has been taught. Could the computer be used to replace some of these unending "dittos" and worksheets? Could we find programs that present individualized drill and practice, AND correct the students' work, AND record the students' progress? Could a teacher get a printout of the drill and practice record for report cards, for parent conferences, for the child himself? At the lowest level, computers can be sued to randomly generate problems and record the correct number of responses. After twelve years of teaching, I learned to rely on that "worksheet time" for one group of students, in order to individualize instruction with others. However, I believe that elementary teachers are master organizers. I believe that teachers can develop new routines to incorporate the use of the computer, to create time to work more with students on difficult concepts, and to relegate some of the busy work to the computer.

   In addition to basic drill and practice, there are opportunities to use the computer to reinforce difficult concepts. There is software available to practice constructing geometric proofs, to analyze equations, to plot graphs of equations, even to the point of graphing functions in calculus. There are many levels of drill and practice. Until fundamental changes are made in the curriculum, teachers will find that the computer can be used as a tool along with more traditional reinforcement techniques.

2. Programming: Traditionally, computers have been used for teaching programming languages. Four or five years ago, some elementary students learned some BASIC programming; some students continued programming classes in junior and senior high school. Many young programmers shared their expertise by creating and writing their own computer games for themselves and other students. Some students, classified as low-achievers, have been attracted to programming. and have demonstrated a certain skill and creativity in the use of computers. However BASIC programming isn't necessary for all elementary students.

   LOGO as a programming language provides much more opportunity for elementary students to learn programming procedures in a creative environment. In addition, working with LOGO develops a child's problem-solving skills and understanding of graph related relationships. LOGO can be used to create a child-centered learning environment with computers.

LOGO classes are typically open-ended and encourage creativity. This environment of experimentation and creativity can be noisy and exciting. Children clamor to share their discoveries in this setting. The traditional elementary classroom isn't designed for this type of "instruction." It's difficult to "give up" control after working so hard to develop a classroom routine. But, as a teacher, I had spent a great deal of time trying to teach the kids to be "creative." LOGO could be a means for trying to teach the children to take control of their own learning, to set their own goals.

3. Applications: I have noticed recently that there is a greater desire to use computers in real-life situations. Most computers have a "spreadsheet" program available. Students can learn to "set up" a spreadsheet with specific formulas for specific situations. Even young children can use a spreadsheet to develop a formula to create an addition or multiplication table. By doing this the student uses the computer as a tool to solve a problem. The mechanics of the arithmetic are left to the computer, based on the formula developed by the student. As a teacher, I spent time teaching facts, algorithms, and formulas. It was then time to teach the children to apply the these appropriately. It was DIFFICULT. How much more sensible it is to teach the children the skill of building, for themselves, formulas for the solution to problem, and have the computer do the computations.

   Additionally, spreadsheets can be used to enhance the teaching of estimation. How often is an elementary student asked for an estimated answer only to give an outlandish figure in reply? Children can use a spreadsheet to do repeated calculations with minor changes in the "data" they can see successive changes in the results. Children can be encouraged to make extended estimations, the computer does the actual calculations.

   Finally, the communications capability is one of the unique strengths of the computer. By "accessing" state and national information sources, students can develop a broader view of education. A classroom set of encyclopedias is no longer the sole source of information. The morning newspaper becomes "old" news by mid-morning. What type of consumer decision-making lessons could be developed in the elementary classroom based on nearly instantaneously "current" stock prices? Computer communications systems could be used as an invaluable tool to teach children to make decisions based on adequate and current information.

There are many programs and computers in the schools today that can be used in the instruction of mathematics. When the truly creative and innovative instructional software does not exist, there are still many strong applications available. I believe that the first step is knowledge. The elementary classroom teacher must learn about and learn to use computers. There are numerous courses available from colleges, universities, even recreation departments. Next, the classroom teacher should make computer decisions based on the current curriculum AND the teaching style that she is comfortable with. Finally, the teacher of mathematics should remember that there are many computer applications available that may not be labeled "mathematics." Look for appropriate software and use it in all academic areas, at all educational levels.

Based on my experience as a Tandy Corporation representative, I believe that many teachers, especially at the elementary level, are not comfortable with computers. Teachers are not taking control of decisions about technology. And yet, the strength of the educational system has always been in the teachers. When we know and learn more, we can take control.

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CHERRY CREEK EQUALS IN COMPUTERS: A MODEL FOR STAFF DEVELOPMENT

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"100 new mathematics computer software packages appear on the market every month. Howmany of these are for drill and practice?"

"In January 1983, nearly 70% of the schools in affluent areas had at least one microcomputer. What was the percentage for low-income areas?"

"Women purchased 45% of the new cars sold in 1983. What percent of the microcomputers did women purchase?"

At the beginning of the Cherry Creek EQUALS in Computers workshop, participants collect answers to "Computer Startling Statements" such as those stated above. Educators are surprised to learn that 90% of all new mathematics software marketed uses the drill-and-practice mode, only 40% of the schools in low-income areas in 1983 were equipped with at least one microcomputer, and women purchased only 2% of the microcomputers sold in 1983.

Computer Equity Issues

The "Startling Statements" activity stresses one of the three themes of EQUALS' workshops: increasing teachers' awareness and understanding of the equity issues in computer education in relation to their own students. Many of the workshop activities focus on the second theme: increasing teachers' confidence and competence in using the computer and integrating it into the curriculum. The third theme reflected in the workshop activities focuses on increasing teachers' knowledge of career options in computer-related fields in order to encourage and motivate students to consider scientific and technical fields of study and work. Awareness - Competence and Confidence - Encouragement. This trio of themes is woven into all Cherry Creek EQUALS in Computers activities.

The Cherry Creek EQUALS in Computers inservice program is modeled after the EQUALS in Computer Technology program developed at the Lawrence Hall of Science, University of California, Berkeley, California. During the 1984-85 school year, forty local educators participated in the Cherry Creek program, designed for people with varying levels of computer knowledge from the novice to the experienced user.

Some comments by the participants about the program:

"Today's session was again lots of fun and challenging. Non-threatening climate made the day even better. I like the group cooperation . . . I'm really anxious to work on the computers at school - no longer afraid of the "monster."

"The day was worthwhile and well-organized. I like the overview of all the issues and software."

Awareness of Student Attitudes

Elementary and middle school teachers gain awareness of their students' attitudes towards computers by asking their students to imagine that they are 30 years old and to describe how they would be using a computer. Teachers found that females would have computers "running the

house and changing diapers". Males would use the computer to "run their business" and for "designing and programming".

High school teachers gathered enrollment data in the elective computer science courses. They discovered that enrollment in introductory programming classes is close to 50% female; however, in the advanced programming courses the ratio of girls to boys is 1 to 2, and the Advanced Placement computer science courses have fewer than 20% female enrollment. By conducting this research, teachers recognize that an equity problem exists and they gain ownership of the problem.

Hands-on Confidence and Competence

Teachers gain confidence and competence in using the computer by experiencing a variety of hands-on computer activities. All participants learn or enhance their knowledge of the Logo language, which can be used as a problem-solving tool with students at all grade levels. The Logo language is particularly appealing to mathematics teachers because it gives students an opportunity to learn geometric concepts in a creative, enjoyable atmosphere.

Two pre-programming activities, "Flipbooks" and "Robots", prepare students for learning Logo. Children learn the basic principles of pictured motion by participating in "Flipbooks", an activity especially appropriate for younger children. In "Robots", students assume the roles of robots and their programmers while practicing giving and following accurate instructions. Planning and cooperation skills are reinforced in this activity.

Software Evaluation

Participants in Cherry Creek EQUALS in Computers spend a significant amount of time critically evaluating software. A variety of problem-solving programs are demonstrated followed by a discussion of the attributes of a high-quality piece of software. For example, in THE FACTORY students are challenged to create geometric "products" on a simulated machine assembly line that they design. Students develop spatial visualization and inductive reasoning skills by using the problem-solving strategies of determining sequence, analyzing a process, and working backwards. Other mathematics software packages which stress problem-solving skills include THE POND, GERTRUDE'S SECRETS, and GERTRUDE'S PUZZLES for elementary students, ROCKY'S BOOTS and MATH WORLDS for middle school students, and GRAPHING EQUATIONS for high school students. In addition, ways in which to integrate general-use programs such as THE PRINT SHOP and CROSSWORD MAGIC into the classroom are explored.

Computer Operation

A last type of hands-on computer activity enables teachers to gain confidence in operating the computer. In the "Apple Index", practical skills such as initializing a blank diskette and using system-master utility programs such as COPYA and FID are learned. In the cooperative off-line activity, "Limerick Machines", students practice diagnostic skills by figuring out what is wrong with a limerick and how to correct it. These diagnostic skills can be extended to computer technology, simulating the process of debugging a computer program and troubleshooting hardware problems.

In addition to time spent working on the computer, workshop participants complete several off-line computer activities which reinforce the thinking skills required to understand computers. Among the confidence-building activities included in the workshop are "Max/Min", "Attribute Machines", the "Bubble Sort", and "Aunt Babe's Road Rallyes".

* "Max/Min" is a cooperative programming activity in which each individual practices

being part of a computational algorithm. The problem at hand is successfully solved by each member of the group cooperating and sharing their resources.

* Practice using the logical operators "and", "or", and "not" is gained in "Attribute Machines". This activity uses concepts from Boolean algebra necessary to become a proficient programmer.

* Students sort themselves according to various criteria using a well-known sorting algorithm in "Bubble Sort".

* In the popular "Road Rallye" activity, students follow directions while traveling on the map of Nedbury, North Dakota. The concepts of default, precedence, and scope encountered in computing are explored in this fun-filled activity.

The aforementioned off-line activities were developed by the EQUALS project to help educators and their students gain knowledge of important computer concepts. Students acquire confidence and competence in carrying out these cooperative activities.

Computer Career Information

To encourage and motivate students to learn about computers and their applications, role models are invited to speak to workshop participants. The role models -- women and members of minority groups who are successfully employed in computer careers -- discuss successes they've had and obstacles they've encountered working in these predominantly white male fields. By listening and talking to these role models, teachers gain insight into the options open to their students and become motivated to bring role models into their classrooms to encourage their students to continue to take the courses that will enable them to consider a computer-based career.

"Computers on the Job" is an activity that gives teachers a chance to explore career options available to their students. Each individual explores ways in which computers are used in one of a variety of fields including medicine, law, real estate, science and engineering, hotel and travel, and creative arts. Follow-up activities may include taking field trips to various organizations which use computers or organizing a computer fair at school which focuses on the use of computers in the work force. Girls, in particular, will be more motivated to learn about computers if they can see their potential uses as problem-solving tools with a variety of applications.

Conclusion

If we are to ensure that all our students are exposed to the exciting world of computer technology, we must first give all teachers experience with computers. If we educators become aware of the issues facing us in achieving computer equity, become confident and competent in using this new technology, and learn techniques to encourage and motivate our students to want to study computers, we will be prepared to teach our students with and about computers. The Cherry Creek EQUALS in Computers inservice program can accomplish these goals.

(For more information about the Cherry Creek EQUALS in Computers program, please contact: Mattye Pollard, Cherry Creek High School, 9300 E. Union Ave., Englewood, CO, 80011.)

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ONE CASE WHERE THE COMPUTER PROVIDES AN UNQUESTIONED ADVANTAGE

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As a math instructor with a knowledge of various learning theories, how would you design a lesson to complete this objective?

OBJECTIVE: Given a quadratic equation, the learner will be able to identify the graph as either a parabola, hyperbola, ellipse, or other.

You could prepare overhead projectuals or handouts showing various equations and their related graphs. However, you would then be doing all the work while the students passively read along. A worksheet requiring students to plot points and then draw the graph might be useful, but realistically, wouldn't students be spending an inordinate amount of time completing computations that are not related to the objective at hand? Technology can be of great assistance in this situation.

A computer (with software such as ARB PLOT or MECC's "Polygraph") could be rolled into the classroom. Along with a large monitor or television, the students could observe as a person in the class entered in various equations to display their graphs on the video screen. Within seconds, the axes can be set up and the range of points for the graph can be displayed by the computer. The computer completes the actual plotting of points. The teacher preparation time to learn to operate software (ARB PLOT is recommended) to direct this lesson is less than 20 minutes. Once comfortable with the software, the time needed to enter an equation and have its resulting graph displayed is less than 15 seconds. MECC's "polygraph" is less powerful and not as easily adaptable for some equations.

For the student, the objective of the lesson comes to life! No longer are students passive observer. Students now become actively involved in determining for themselves patterns in the graphs of equations, a form of discovery learning. Easily mastered, ARB PLOT allows the students to enter their own equations and quickly see their graphs. The students can enter several equations and see each simultaneously (superimposed). An example could be having the students enter four equations of the form:

$Y = aX^2$, where 'a' has the values; -5, -1/2, 2, and 7.

In this case the student could see the effect of changing the leading coefficient in a parabolic equation.

I have used both "Polygraph" and ARB PLOT with excellent success in my honors algebra class for 9th graders at Centennial JHS. The advantages of having the students try a wide range of equations and <u>discover for themselves</u> the properties of equations and the effect of changes on their related graphs, far out-weighs any number of pages in any text that attempts to do the work for students. For the slower student, the computer can provide the means to achieve the objective more quickly and with fewer difficulty. For the gifted student, the computer provides the opportunity to freely explore equations and their graphs, and at an individual rate. ARB PLOT can provide the graph for any polynomial the student enters . . . and do this for each student independently of the other students. This is a distinct advantage over more traditional non-computer aided methods.

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NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS

THE IMPACT OF COMPUTING TECHNOLOGY ON SCHOOL MATHEMATICS

REPORT OF AN NCTM CONFERENCE

One of the critical problems facing mathematics education today is the need for curricula and instructional methods to respond to the influence that computing technology is having on mathematics and its teaching. Numerous conferences, reports, and projects have focused on different aspects of the effect of emerging technology on mathematics curricula and instruction. For example, the Conference Board of the Mathematical Sciences produced a set of guidelines that identified fundamental topics in K–12 mathematics (CBMS 1983), and an NSF-sponsored conference at the University of Maryland resulted in a document that provided insight into the effect of the computer on subjects in the traditional secondary mathematics curriculum (Fey 1984).

NCTM has made many efforts to provide leadership as decisions about the impact of computing technology on mathematics education are made. In 1981 its Board of Directors established the Technology Advisory Committee, which has subsequently engaged in several projects and activities that serve members in the area of technology and which advises the Board on matters relating to technology and mathematics education. NCTM sponsors a continuing series of seminars for K–12 mathematics teachers on the uses of computers in mathematics instruction and has for a long time devoted program slots at regional and national meetings to issues associated with the impact of technology on mathematics education. The publications of NCTM, including the journals and the 1984 Yearbook, reflect the continuing concern of the organization with this issue.

In an effort to continue its leadership role, NCTM and the Center for Mathematics Education of the University of Maryland, with financial support provided by the National Science Foundation, sponsored a conference at NCTM headquarters during March 1984 to consider "The Impact of Computing on School Mathematics." Participants represented a number of interested constituencies: government funding agencies, commercial publishers of mathematics materials, the standardized testing industry, mathematics teacher educators, mathematicians, computer scientists, elementary, middle, and secondary mathematics teachers, and district-and state-level mathematics supervisors. Participants were asked to respond to a series of questions related to the impact of computing technology on the mathematics curriculum, mathematics instruction, and mathematics teacher education, and to formulate general recommendations in each of these areas. The conference produced the recommendations herein—each gaining broad, if not unanimous, support.

RECOMMENDATIONS ON CURRICULUM, INSTRUCTION, AND TEACHER EDUCATION

Prologue

Applications of calculators, computers, and other electronic information technology are reshaping the fundamental methods of doing and teaching mathematics. When used as tools for arithmetic and for the analysis of graphic or symbolic data, calculators and computers offer powerful new approaches to familiar problems and access to entirely new branches of mathematics. Applications of these same capabilities to instruction are bringing major changes to mathematics classrooms and the roles of mathematics teachers.

The major influence of technology on mathematics education is its potential to shift the focus of instruction from an emphasis on manipulative skills to an emphasis on developing concepts, relationships, structures, and problem-solving skills. Traditional precollege mathematics curricula have stressed the development of a variety of mechanical procedures, including the computational algorithms of arithmetic and the transformation of symbolic expressions in algebra, trigonometry, and analysis. The use of calculators and computers as standard tools in quantitative problem-solving situations, however, has diminished the value of human proficiency in the execution of such procedures. Much of the instructional time currently devoted to acquiring proficiency with paper-and-pencil algorithms should be reallocated to support a range of new or previously neglected topics that have a valid place in the K–12 mathematics curriculum. Moreover, teacher education programs must be modified to reflect these changes in school mathematics content and to model the delivery of instruction through appropriate applications of technology.

The proposals that follow are intended as guidelines for selecting the content of precollege mathematics curricula, for teaching that content in a manner that takes advantage of emerging technology, and for designing teacher education programs that recognize the changing curricular patterns and instructional roles for teachers. The proposals are based on five fundamental assumptions:

1. Coordinated change can take place simultaneously at all levels of mathematics instruction.
2. All students and teachers will have access to calculators and computers for the study of mathematics, in the classroom and at home.
3. All students will experience appropriate application of computers in the study of each school discipline.
4. State/provincial, district, and local mathematics curriculum guidelines and criteria for mathematics textbook adoption will be rewritten to reflect the changing priorities of school mathematics.

5. The publishers of standardized tests and instructional materials will
   (a) immediately begin developing products that are consistent with the changing objectives of precollege mathematics;
   (b) continue support for that development on a schedule that facilitates the implementation of proposed curricular changes.

TECHNOLOGY AND THE MATHEMATICS CURRICULUM

Today, the computational skills of arithmetic, algebra, geometry, trigonometry, and calculus dominate the K–12 mathematics curriculum. The content and sequences of courses are planned carefully so that students acquire intricate hierarchies of prerequisite skills for each major computational algorithm. Although these well-known mathematical procedures originated as essential aids to efficient problem solving, most of the algorithms of school mathematics have now been programmed for rapid execution by calculators and computers.

To do arithmetic today, mental operations are best for obtaining quick approximations; calculators are the tools of choice for one-time computations; and computers are most appropriate for repetitive calculations. In algebra, trigonometry, and calculus, computers can execute the numerical and symbolic manipulative procedures that students spend countless hours mastering.

As a consequence of this changing environment for mathematical work, the curriculum in grades K–12 needs careful reassessment and revision. Classroom teachers, mathematics supervisors, members of state departments/provincial ministries of education, authors and publishers of textbooks, developers of standardized tests, and other curriculum developers must consider the following recommendations and the questions they raise.

Elementary School Level

The elementary school mathematics curriculum has traditionally focused on developing students' skills in computing with whole numbers, fractions, decimals, and percents. Since computers and calculators can perform such operations more quickly and accurately than can usually be done otherwise, the traditional goals of elementary school mathematics must be reexamined and the predominance of computation-related objectives must be reassessed. Curriculum developers are urged to consider the following recommendations that suggest a broadened view of mathematics appropriate for grades K–4.

- Calculators should routinely be available to students in all activities associated with mathematics learning, including testing. Students should be taught to distinguish situations in which calculators are appropriate aids to computation from situations in which mental operations or paper-and-pencil computations are more appropriate.
- Emphasis should continue to be placed on students' knowledge of basic facts required for proficient mental arithmetic and estimation. However, significant portions of elementary curricula devoted to algorithms for multiple-digit calculations can be eliminated.
- Instruction must shift to emphasize the meaning of arithmetic operations. Such undestanding is essential for problem solving.
- Experience with physical manipulatives and other concrete representations of concepts must continue to be an important phase of learning mathematical ideas. Because of the increased instructional emphasis on meaning and understanding, this activity must not be overlooked as the curriculum evolves to take advantage of computers and calculators for instruction.
- Because computers and calculators can be used effectively in teaching mathematical concepts, no a priori assumptions should be made about the appropriateness of any given mathematical topic for elementary students. For instance, decimals, negative numbers, and scientific notation appear naturally when using calculators and can be taught as they arise. Computers facilitate an early introduction to geometric concepts such as transformations, congruence, and vectors; statistical concepts such as randomness; and algebraic concepts such as variable and function.
- Preprogramming activities and simple computer programming in Logo or BASIC can be done by students as early as the kindergarten level to convey both mathematical and computer concepts. Computer literacy should come as a natural by-product of such experiences rather than as a special addition to the elementary school curriculum.

Middle School Level

The mathematics curriculum for the middle school (grades 5–8) must take into account incoming students' knowledge of new topics such as computing, their understanding of topics formerly reserved for the middle grades, and their more limited skills in topics such as arithmetic algorithms. In addition to building on the changes proposed for the elementary grades, curriculum developers for the middle grades should consider the following specific recommendations.

- Mathematics in the middle grades should emphasize the development of "number sense"—the intuitive feeling for the relative sizes of numbers that is essential in skillful estimation, approximation, mental arithmetic, and the interpretation of results for reasonableness.
- Some portion of instructional time should be given to the study of discrete mathematics, including counting, graph theory, probability, and logic, which is important and appropriate for the middle grades.
- Calculators and computers can be used to teach iterative procedures for solving significant problems before traditional formal methods are presented. Such experiences should be part of the middle school mathematics curriculum.
- An introduction to statistics should include extensive gathering, organization, and presentation of data. Important concepts can be developed in the context of real data sets whose manipulation and examination is aided by computer analysis and graphing software.

- Middle school mathematics programs should take advantage of the visual display capabilities of computer graphics that support and underscore the importance of informal geometry objectives. Transformations, mensuration formulas, and spatial visualization can be vividly illustrated by using computer graphics.
- Increased emphasis should be placed on such nontraditional methods of problem solving as organized lists, guess and check, geometrical sketches, and successive approximations, all of which are made feasible by calculators and computers.
- Computer programming experiences that introduce the concepts of variable and function should be provided. These experiences should help prepare students for the study of algebra.
- By the end of grade 6, students should be able to write simple computer programs that require looping and branching concepts. The emphasis in such programming activities should be on problems that convey significant mathematical ideas.

Senior High School Level

Developers of senior high school mathematics curricula must consider both the changing preparation of their entering students and the changing college and work environments their graduates will enter. The following recommendations are suggested as guidelines for the curricular evolution that must occur if high school mathematics programs are to reflect appropriately the influence of technology on mathematics and its teaching.

- The selection and sequencing of high school mathematics for college-bound students should no longer be governed solely by preparation for calculus. The most important mathematics for many students will consist of topics from discrete mathematics and statistics. High school programs must reflect these goals in their content and priorities.
- Computing is changing calculus and its traditional prerequisite subjects. Computer symbolic systems, graphics, and numerical analysis software make student mastery of manipulative procedures less important and, at the same time, offer dynamic tools for the illustration of fundamental concepts and processes. Such changes should be considered as the influence of calculus on high school mathematics is assessed.
- The content priorities and approaches to topics in high school geometry should be reconsidered in light of computer graphics and their applications. The geometry of three-dimensional space, trigonometry, vectors, coordinates, and transformations are all made more accessible with computer assistance through visual displays and complex calculations.
- The skill objectives of algebra must be reassessed to identify those procedures more easily done by computer (e.g., combination of expressions or solution of equations) or calculator (e.g., values of trigonometric functions, logarithms, or exponentials). The properties of elementary functions are still important for modeling quantitative relationships, but proficiency in many familiar computational processes is of little value.
- In many topics of high school mathematics, computers and calculators can be used to discover and test principles and methods. For example, concepts and theorems can be illustrated numerically and graphically to develop sound understanding before formal proof is attempted.
- For high school students with limited ability or interest in mathematics, technology offers an opportunity to enrich curricula with realistic problem-solving situations without insisting on a mastery of skill prerequisities. For example, these students can concentrate on the skills needed to collect, organize, and interpret mathematical information, skills appropriate for estimation and approximation, problem-solving strategies, data analysis methods, and reasoned evaluation of results.

The time needed for new curricula will probably exceed the time that can be saved by reduced emphasis on topics of diminished importance or by a more efficient organization of instruction. Mathematics is of such fundamental importance, however, that schools must allocate more time to its study. This means more minutes per day in the elementary and middle grades and more years of mathematics in secondary school.

TECHNOLOGY AND MATHEMATICS INSTRUCTION

The impressive capabilities of emerging technologies promise major changes in the organization of mathematics instruction and in the roles of students and teachers. Computers offer a dynamic electronic chalkboard for the demonstration of mathematical ideas. As laboratory tools, they assist in the exploration and discovery of concepts, the practice of skills, applied problem solving, and instruction by simulation. Computer-based evaluation and information management provide further opportunities for change in traditional teaching/learning patterns.

Although there may be risks associated with changing instructional patterns and teachers' and students' roles, the potential for improved instruction in mathematics makes the search for ways to reduce those risks worthwhile. If teachers and students are to exploit the potential of technology to support instruction, they must become adept at the new roles described in the recommendations below.

One of the most immediate consequences of the integration of technology into mathematics instruction is the increased need for teachers to make informed decisions about questions that relate to certain aspects of the mathematics curriculum. The following recommendations focus on these issues.

- Teachers must be able to make informed curricular decisions about the appropriate place and strategy for using technology to enhance instruction.
- Teachers must learn how dynamic visual displays made possible by computers can aid transition from concrete experience to abstract mathematical ideas.
- Teachers must become adept at interpreting and elaborating computer-based evaluation of student learning and in using information management systems that organize curriculum options and assessment data.

New roles for classroom teachers and students are also made possible by technological enhancements of mathematics instruction. Among these roles are the following:

- Teachers must become effective catalysts for student-directed learning. They must be able to pose stimulating problems and to probe student understanding with questions that begin "What would happen if . . .?"
- Teachers must serve as learning models in attacking mathematical questions. They must be comfortable assisting students in learning situations in which the topic being studied or the resource employed is unfamiliar. Teachers must be prepared to say, "I don't know yet," while they join students in exploration.
- Teachers must become facilitators of cooperative learning as students engage in realistic learning projects that computers make attractive. Teachers and students must emulate real problem solvers as they deal with problems of complexity, accuracy, and precision that occur in the collection and analysis of real data.
- For students, the greatest promise and challenge of technology in mathematics learning is the move toward more self-directed and self-monitored learning. Students must become adept at using computer-based instructional materials, mathematical tool software, and personal programming skills to develop and practice the use of mathematical concepts, principles, and problem-solving processes.
- Student-directed learning suggests that students may become dispersed throughout the learning environment. Teachers must know how to maintain effective communication with and among learners and must recognize that individualized technology-enhanced learning is not synonymous with independent study.

The fundamental theme that underlies recommended changes in patterns of mathematics instruction and in the roles of teachers and students is the emergence of a new relationship among teachers, students, and the subject matter. The presence of computers and calculators in demonstration, practice, problem solving, and evaluation creates a new classroom dynamic in which teachers and students are natural partners in the search for an understanding of mathematical ideas and a solution of mathematical problems.

TECHNOLOGY AND MATHEMATICS TEACHER EDUCATION

The recommendations in previous sections of this report suggest a new look to mathematics classrooms, with concepts and problem solving the focus of curricula and teachers joining their students as active partners in learning. If these changes are to occur, classroom teachers must be the primary agents of change. Consequently, preservice and in-service mathematics teacher education programs must be restructured to prepare teachers for their new roles.

Computer education for teachers of mathematics requires understanding and skill in three areas: (1) the uses of computers and calculators as problem-solving tools in mathematics; (2) the uses of computers for the presentation, evaluation, and management of instruction; and (3) the concepts of computer literacy that contribute to, or depend on, the knowledge of mathematics. The breadth and depth of appropriate computer education will vary with the teacher's grade level and subject specialization. The following recommendations provide guidelines to the content and form of preservice and in-service experiences suitable for elementary, middle, and senior high school mathematics teachers.

Mathematics content and methods courses in teacher education programs must be examined and restructured to give more attention to priority content areas and to make calculator and computer use an integral part of all such courses. In particular, the following recommendations apply:

- Students preparing to teach at the elementary level must complete the mathematics requirements outlined in the *Guidelines for the Preparation of Teachers of Mathematics* (NCTM 1981), with special emphasis on estimation, approximation, mental arithmetic, data organization and analysis, informal geometry (using a variety of approaches to the subject that reflect its visual nature such as transformations, vectors, and coordinates), probability concepts, and measurement concepts.
- Computer literacy and programming concepts needed by elementary teachers should be acquired through experience in the mathematics content and methods courses. Consequently, teachers preparing to teach at this level need not be required to take a formal computer science course, although a course focusing on computer applications in education is recommended.
- Students preparing to teach at the middle school level should also complete the mathematical requirements outlined in the NCTM *Guidelines* for this level, with special attention to the priority topics recommended for elementary teachers and experience with more advanced topics from algebra, analysis, statistics, and discrete mathematics.
- Middle school mathematics teachers should complete a course on computer applications in education and a computer science course that focuses on problem solving and, more specifically, on the nature of algorithmic thinking and the computer implementation of problem solutions.
- Students preparing to teach mathematics at the secondary level should complete the mathematics major outlined in the NCTM *Guidelines* and coursework in discrete mathematics, probability and statistics (including exploratory data analysis), and numerical analysis. All topics must be taught in ways that demonstrate appropriate applications of computing to mathematics.
- In addition to the computing courses recommended for middle school teachers, secondary mathematics teachers should complete study that provides further experience with structured programming, algorithmic thinking, mathematical modeling, and other mathematics fundamental to computer science.

To provide teachers of mathematics with the knowledge and skills needed to use computers and other technology effectively for instruction, programs of preservice and in-service education must include the following components:

- Level 1 (awareness). Through the use of computers, calculators, and other technology as an integral part of the delivery of instruction in mathematics, teachers must be exposed to a variety of applications that

enhance their understanding of the potential of these technologies. They must experience a range of hands-on activities and explorations and see demonstrations of appropriate uses of technology in classrooms.

- Level 2 (interaction with prepared software). Teachers at this level must be given training in the selection and use of appropriate software to enhance instruction in mathematics, and information should be given to them about sources of mathematics-related software. They must develop, deliver, and evaluate lessons and units that integrate existing software into mathematics instruction.
- Level 3 (interaction with programming). Teachers should be given the opportunity to engage in programming-related activities such as tracing, debugging, or modifying existing programs, all of which can enhance mathematics learning. Such experiences should focus on how programming ideas can be used to teach mathematical concepts, not on developing the teacher's personal programming skills.

The most important point in these recommendations for change in mathematics teacher education is the requirement that preservice and in-service programs must model the desired changes. Teachers must *experience* mathematics content and methods courses that emphasize priority topics and that present those topics using a variety of techniques that fully integrate computers, calculators, and other information-processing technologies. The realization of this goal will require commitment and cooperation among mathematics and teacher education faculties. Institutions must commit needed resources for equipment and must support faculty study time.

- Every institution should identify a computer resource teacher who can serve as a technical advisor for all teachers and a mathematics/computer resource teacher who can provide leadership in helping teachers make appropriate use of computing devices in mathematics instruction. Institutional support for training such individuals will be needed.
- Institutions must provide ongoing support mechanisms. Administrators must be educated about proposed changes in mathematics content and the delivery of instruction and must be supportive of changes. Initiative and achievement must be recognized.
- Colleges and universities should work with local schools and districts to devise creative models for in-service programs to upgrade teachers' backgrounds and ways to provide support for teachers as changes are implemented. Such programs must build in mechanisms to inform teachers at upper levels about curricular and instructional changes at lower levels and vice versa.
- Professional organizations such as NCTM must offer training workshops to prepare teacher educators for leadership roles in effecting change. Funding agencies must offer support for retraining activities.

Well-educated, committed teachers will be the key to the successful implementation of curricular and instructional improvements. The computer education of preservice and in-service teachers represents a critical investment necessary for change to occur.

Bibliography

Conference Board of the Mathematical Sciences. "The Mathematical Sciences Curriculum K–12: What Is Still Fundamental and What Is Not." In *Educating Americans for the Twenty-first Century (Source Materials)*. Washington, D.C.: National Science Board Commission on Precollege Education in Mathematics, Science, and Technology, 1983.

Fey, James, ed. *Computing and Mathematics: Impact on Secondary School Curricula*. Reston, Va.: National Council of Teachers of Mathematics, 1984.

Hansen, Viggo P., ed. *Computers in Mathematics Education*. 1984 Yearbook of the National Council of Teachers of Mathematics. Reston, Va.: The Council, 1984.

National Council of Teachers of Mathematics. *An Agenda for Action: Recommendations for School Mathematics of the 1980s*. Reston, Va.: The Council, 1980.

———. *Guidelines for the Preparation of Teachers of Mathematics*. Reston, Va.: The Council, 1981.

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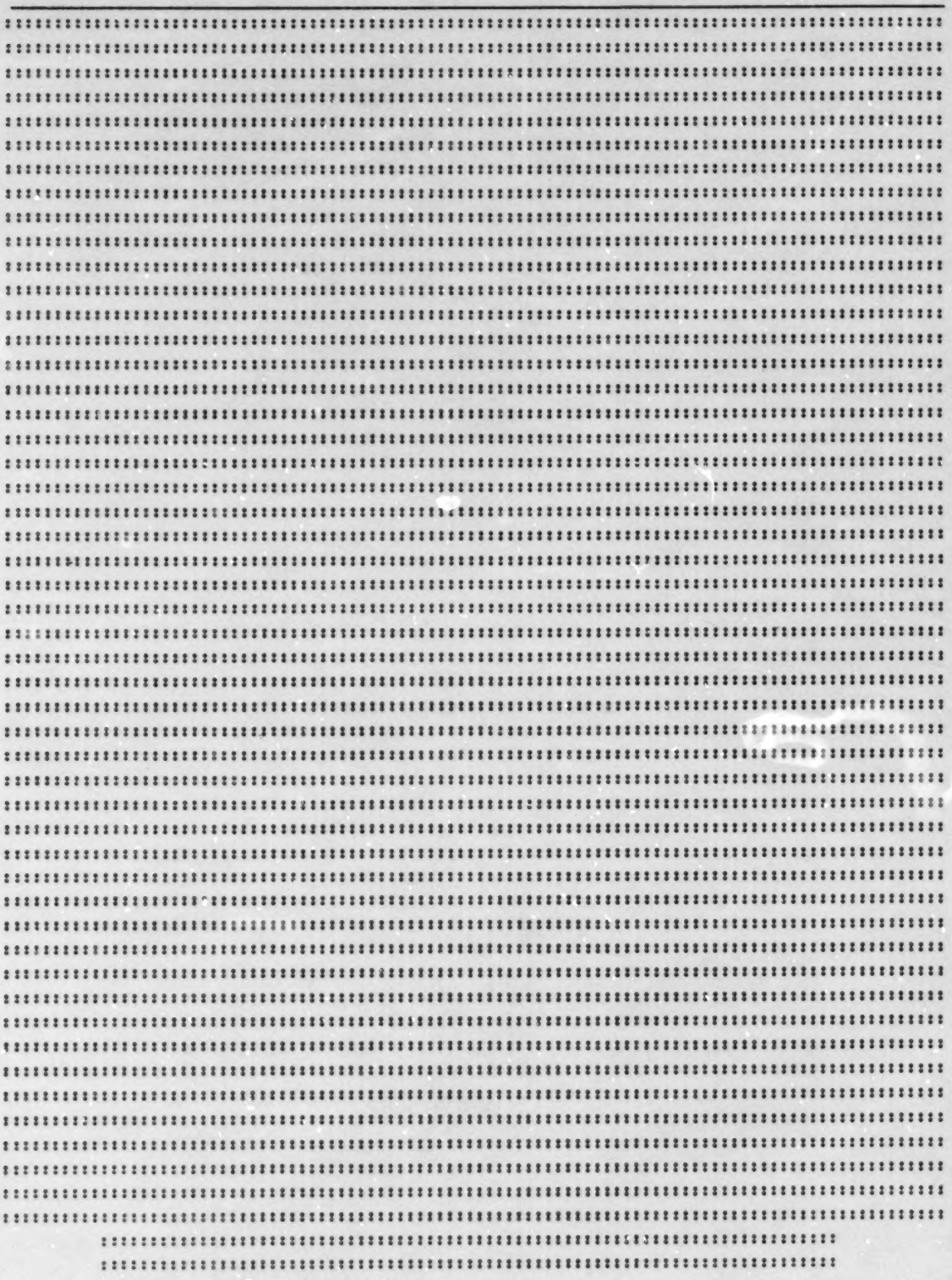

FALL 1985 CCTM ANNUAL MEETING ** FRIDAY ** OCT. 18, 1985 BROADMOR HOTEL COLO. SPRINGS

The 1985 annual meeting of the Colorado Council of Teachers of Mathematics will take place on Friday, October 18, 1985 at the Broadmor Hotel in Coloredo Springs, Colorado. Multiple sessions for mathematics teachers at elementary, middle school, junior high, and senior high school will be held and will include workshops. You are urged to plan early to attend this meeting and encourage to make this information known to others who are interested in teaching mathematics at any level. Further information on the meeting can be obtained from the chair of the meeting; Dr. Ernest Allen, Department of Mathematics, University of Southern Colorado, Pueblo, Coloredo 81001, office phone (303) 549-2693, home phone (303)452-5249.

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